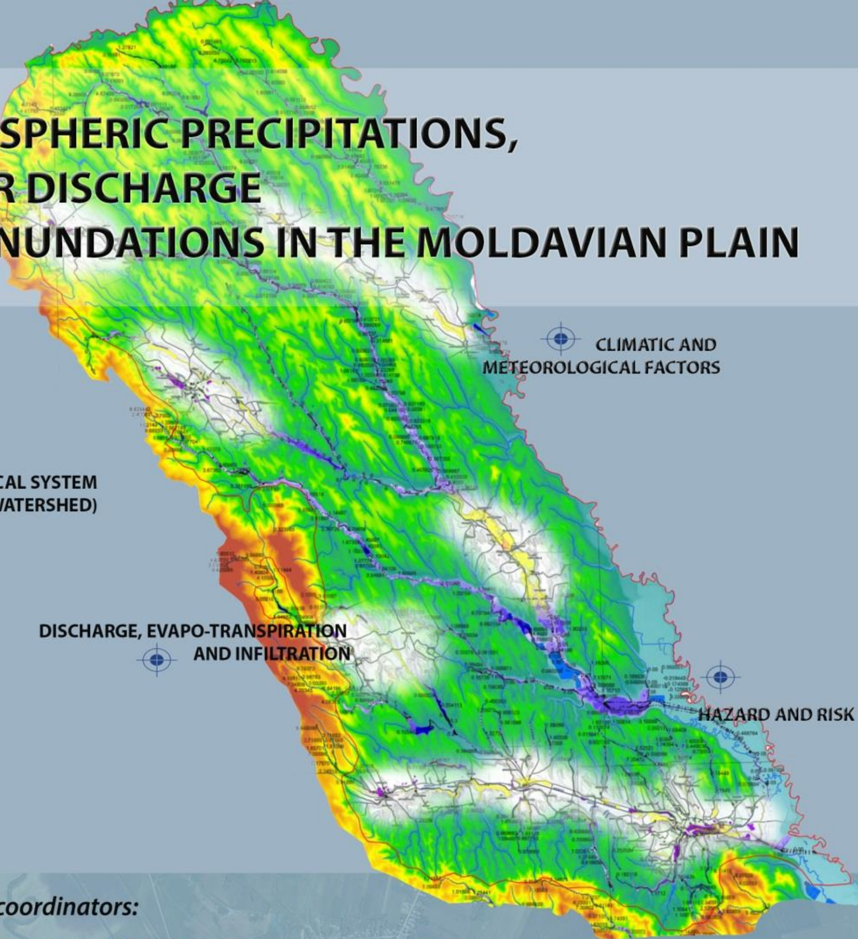
UNIVERSITY OF "ALEXANDRU IOAN CUZA", IAŞI
GEOGRAPHY AND GEOLOGY FACULTY
CHEMISTRY, LIFE AND EARTH SCINECES DOCTORAL SCHOOL

UNIVERSITÉ DE LORRAINE
DÉPARTEMENT DE GÉOGRAPHIE ET AMÉNAGEMENT
ECOLE DOCTORALE FERNAND-BRAUDEL

ATMOSPHERIC PRECIPITATIONS, WATER DISCHARGE AND INUNDATIONS IN THE MOLDAVIAN PLAIN



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DOCTORATE THESIS IN CO-TUTELLE

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THE THESIS CONTENT

Introduction

One of the major challenges of this century is represented by climatic changes and their influence upon the environment. In the case of Romania, the orographic barrier plays the most important role in the delineation of surplus or deficient areas as refered to humidity. In the western and central regions of Romania, with oceanic influences, there is an surplus of humidity, while in the southern, south-eastern and eastern regions, with continental influences, there is a deficient humidity that generates dryness phenomena and drought. Non-the-less, we notice, in the last years, contrast situations with particularities in those regions affected by dryness and drought where there is an surplus of humidity.

Climatic change at global or local level represent a major problem and induce concern among researchers from various disciplines (meteorology, climatology, geomorphology, ecology, hydrology, biology, medicine, sociology etc.) in consideration of change that might produce major setbacks in all the life domains and the socio-economic activities. In this respect, knowledge, research and investigation at detailed level of local and regional meteorological conditions that induce triggering situations for atmospheric hazards generating risks, human and economic losses, sometimes hard to estimate, develop in significant and full of concern attitudes in contemporary times.

In the Moldavian Plain, due to the torrential character of most of the rivers, maximum discharge risk management is still difficult for the tributary/secondary streams. Even if the Jijia watershed, with the main stream of the Moldavian Plain, dispalys numerous water storages since 1960 to 1990, being one of the most systematized hydrographic basins, with tens of kilometers of dams and enbankments, the risks of maximum channel discharge and hillside discharge is still present. The intention of realizing a doctoral study on the Atmospheric precipitations, water discharge and inundations in the Moldavian Plain comes as a result of concerns in this respect and need to identify the natural risks and to evaluate the human activities as a perspective of risk – benefit for the efficient management of natural resources or in the attempt to favour sustainable development. Although floods are natural phenomena, with time repetability, as discharge processes along riverbeds, inundations represent, in modern times, one of the main causes of human and material losses.

1. Geographic location

The Moldavian Plain lies in the north-east of the Moldavian Plateau, between the Prut River corridor and the plateau of Suceava and Bârlad (Figure 3.1). With an average altitude of 125 meters and a maximum altitude of 265 meters in Cozancea Hill, the Moldavian Plain was studied by distinguished geographers over time: I. Rick (1931) names it the *Jijia Depression*, I. Simionescu (1934) calls it the *Moldavish Plain*, M. David (1993) calls it a part of the *Middle Prut Depression*, V. Tufescu (1942) calls it the *Moldavian Plain*. The *plain* denomination refer to its' agricultural land-use, low altitude, cernoziomic soils, Steppe vegetation and it's regime of water discharge. The sense of depression denomination is imposed by its' lower altitude in relation to the neighbouring table-lands which dominate, through 100 m dislevelments. In reality the Moldavian Plain is a low altitude plateau with field-like features, built on marl and clay deposits, with mono-cline character that results in numerous geomorphologic discontinuities.

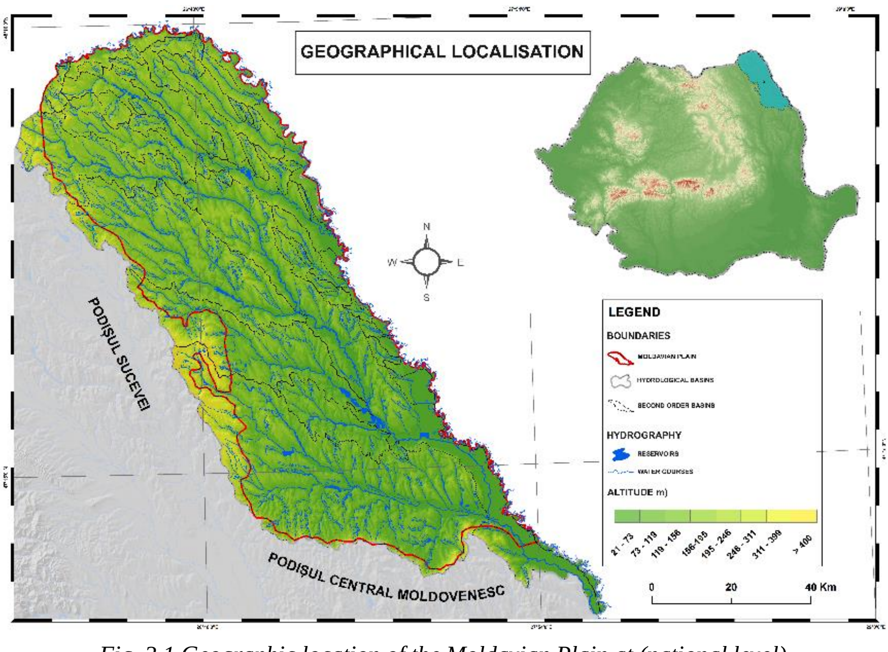


Fig. 3.1 Geographic location of the Moldavian Plain at (national level)

Laying in North-estern Romania, the Moldavian Plain is drained by 5 river

systems: Ghireni, Volovăţ, Başeu, Corogea şi Jijia.
The rivers of Corogea, Volovăţ and Ghireni dispaly their hydrographic basins inside the Moldavian Plain entirely, while Başeu river has 10% of its upper basin in the Suceava Plateau. The Jijia river has 80% of its watershed in the central, Western and Southern parts of the Moldavian Plain. The rest of the watershed, respectivly 20% is fed from the Eastern part of the Suceava Palteau and the Central Moldavian Palteau.

From the hydrographic view point all the rivers in observation pertain to the right part of the larger Prut watershed, developed in the much larger unit of Eastern Moldavian Plateau.

2. The climatic geographic factors to influence the discharge regime of the rivers in the Moldavian Plain.

The geographic location of the region influences, in direct manner, the hydrologic regime. The accumulation of water reserves and their variation in time and space is influenced by the geographic factors, their complexity and the dimensional elements of the hydrographic systems and the source watersheds.

2.1. Air temperature

The geographic repartition of the annual average air temperature is relatively constant with uniform tendencies on wide spaces. The characteristic isotherms describe extended territories. The highest temperatures, usually over 9, 5°C are specific to the south-eastern areas of the Moldavian Plain while the lowest temperatures, below 8°C are specific to the north and north-western areas. The NW-SE differences are notable and explain the latitudinal interval (1°15’), the altitudinal interval (over 150m) and the climatic influence of the neighbouring areas (the northern area is closer to the high plateaus and mountains to the west). There are also thermic differences between the west and the east, in the Moldavian Plain, yet these are less notable (0, 4 °C in average) and are the result of altitudinal differences between two study area compartments.

The central part of the Moldavian Plain displays temperatures in the 8,5 and

9°C interval where the annual average isotherms impress a sinuous route (given by the isotherms elongations toward the upper valley) and a general NE to SW orientation.

The annual average ait temperatures decrease from south to north (9,6°C at Iloaia's Bridge, 8,2°C at Avrămeni, 7,8°C at Darabani) and increase, in general, from west to east (8,6°C at Botoşani, 9,2°C at Stânca; 8,9°C at Cotnari, 9,5°C at Iaşi) as the continental climatic characteristics become more obvious and the altitude decreases (Mihăilă, 2006).

2.2. Atmospheric precipitations

Atmospheric precipitations represent, along with the other climatic elements, one of the important control factors for the individual character of the climate of a region since they influence the geographic landscape assembly. Furthermore, due to their wide spatial and temporal variability, atmospheric precipitations, control the social and the economic activities, mainly: agriculture, transportations, tourism, constructions etc.

2.2.1. Spatial distribution of precipitations

In order to account for a comprehensive analysis of the spatial distribution of precipitations' quantities the study relies on pluviometric data in the 1960-2011 period recorded at 32 meteorological stations and pluviometric posts (9 meteorological stations and 23 pluviometric posts) inside the Moldavian Plain and the surroundings (Fig. 5.1).

Given the non-homogenous distribution of the data at the above mentioned posts we applied an extension of the data series. Furthermore, for a fair analysis and as a consequence of some post and stations dismantling since 1990 or the settling other posts and stations far from 1961 we analyzed the data on two common intervals: 1961 – 1991 and 1981 – 2011. The spatial distribution of the posts and stations enhanced the implementing of a regular network of points (including points in the neighbouring areas of the Moldavian Plain) and supported the development of spatial distribution maps for the annual average precipitations.

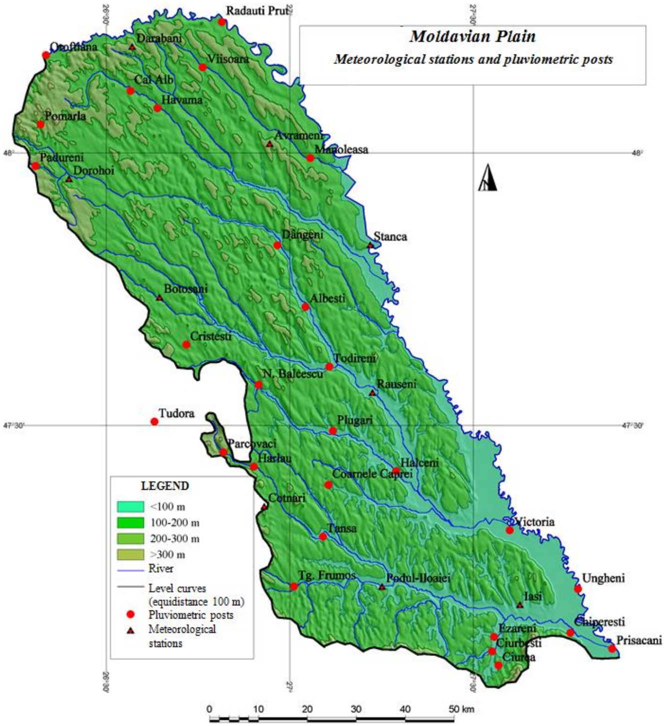


Fig. 5.1 Meteorological stations and pluviometric posts in the Moldavian Plain

The analyses of the obtained maps regarding annual precipitations quantities in the Moldavian Plain reveal the decreasing trend from west to east, along with the decrease in overall altitudes and lower frequencies of humid air masses to the east (drier air masses), compared to more humid, Atlantic, air masses to the west. In addition, the foehnization process of the western side accounts for the reduction of the western and eastern precipitation quantities differences. In the same time, the distribution maps (Fig. 5.2, 5.3) indicate that:

1. The high altitude zones register an increased pluviometric input (Ibăneşti Hills or Darabani Hills, to the north: Pomârla - 623, 9 mm; Copălău - Cozancea – Guranda range, to the central part: Cristeşti - 585, 3 mm, Nicolae Bălcescu - 564, 8 mm). The Bahlui hydrographic basin deserves special attention in the context. The Iaşi *Rib-front*, a 350 meters high relief obstacle in front of the north-western air masses movement generates increased precipitation quantities in the lower Bahlui watershed (where the masses of air start to ascend). The situation becomes obvious

when comparing with the other important valleys (Jijia valley, north of Iaşi – at Victoria, 476 mm).

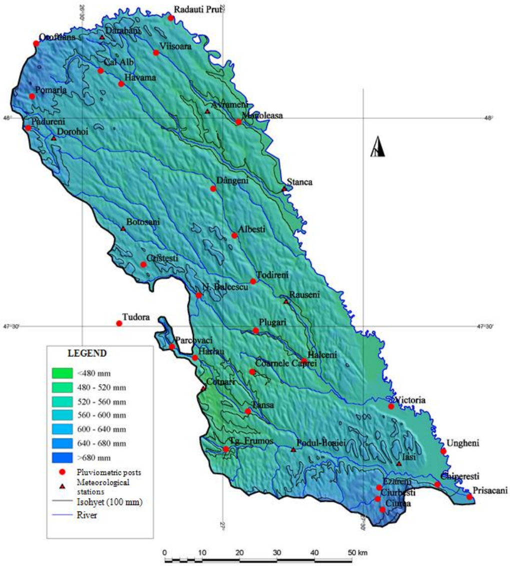


Fig. 5.2 Spatial distribution of the average multi-annual precipitation in the Moldavian Plain between 1961 and 1991

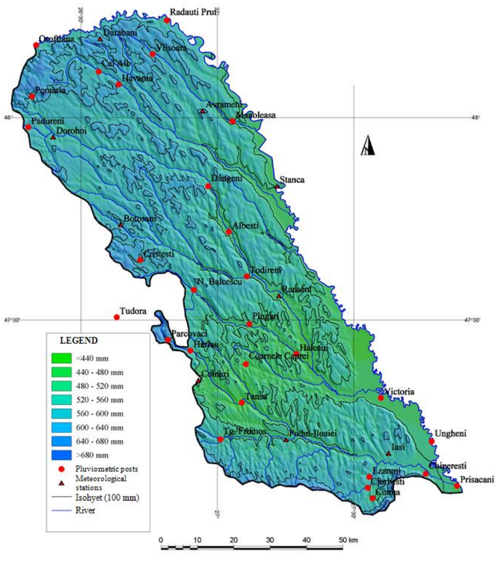


Fig. 5.3 Spatial distribution of the average multi-annual precipitation in the Moldavian Plain between 1981 and 2011

The Iaşi city generates increased numbers of condensation nucleus in conjunction with *thermic chimney* (given by high relative altitudes differences) develops slightly greater precipitations quantities (Iaşi, 573 mm). To the west of Iaşi city there are two *orographic funnels* that entrap, drive and boost the air flows resulting in their ascent. To the south, the opening toward the Prut River and the High Forest Hills (Republic of Moldavia) induce a slight increased precipitation quantity over the year, while in the Ciurea watershed, where the *funnel* is blocked to the south (by the Bârnova Hill) precipitations are very high for this area (compared to the rest of the country, Ciurea 646 mm, Bârnova 775 mm at 354 meters; the quantity is comparable to the mountain area at 700 meters altitude).

2. The lower altitude zones also display the lower annual precipitations quantities. Among them we notice the north-eastern side of the Upper Jijia Plain ac. White Horse 456 mm; the Cliff, 459 mm and the south-western side, in the *shadow* of the Great Hill – Hârlău (Tansa, 467,20 mm; Goat's Horns, 473 mm). A third low precipitation area appears on the Prut River valley.

Aside from the, above mentioned, pluviometric differences there is also an alternative zone of high altitude spots with increased precipitations and low altitude spots with decreased precipitation quantities with a well evidenced trend from north-west to south-east. The versants exposed to the humid air masses from the NW are subject to increased rain input, while the versants exposed to SE drier air masses are subject to decreased rain input. Both air masses categories are subject to foehnization with greater differences between the versants that are opposed to air ascent and those exposed to air ascent, especially when the air masses are of maritime origin.

2.2.2. Spatial distribution of the semestral precipitation quantities

In the warm season (1st of April and 30th of September) the air masses dynamics, very active as a western component and the thermic and dynamic convections with maximum annual values determine, for the warm period, that two thirds of the annual precipitations take place (Fig. 5.4).

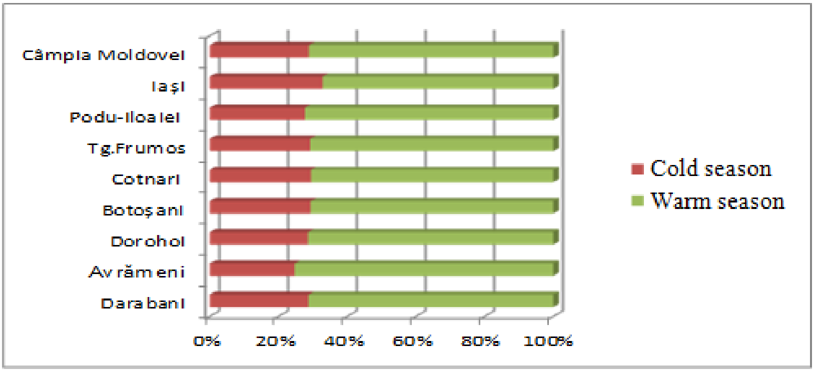


Fig. 5.4 Semi-annual distribution of precipitations quantity in the Moldavian Plain

The spatial distribution of the atmospheric precipitations in the warm semester resemble the annual distribution with notable differences as referred to the recorded values. The greater values are specific to the north and north-west of the study area, to the contact with the Suceava Plateau (Pomârla 413, 3 mm, Darabani - 409, 6 mm).

In the cold semester (1st of October – 31st of March) the precipitations quantities are lower, with only 165, 9 mm as an average of the Moldavian Plain. This happens as a result of higher frequencies of anti-cyclonic air masses and inefficient thermic convections. In this interval the atmospheric dynamic is dominated by drier and colder continental air masses that originate from the north and north-east of Europe or from north-west and west of Siberia.

2.2.3. Spatial distribution of the seasonal precipitation quantities

Relatively constant, the summer is the seasons of the greatest precipitations quantities (42%), followed by spring (25%), autumn (20%), while in winter there the lowest precipitation quantities (13%). Approximately the same temporal distribution is to be found for the absolute values of the seasonal sums of precipitations at each meteorological station and pluviometric post (Fig. 5.9).

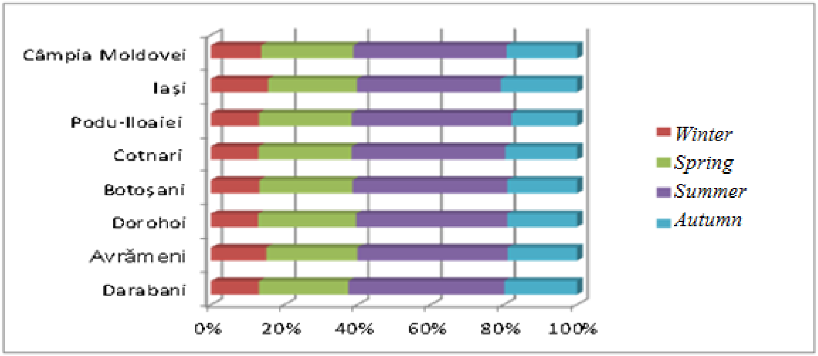


Fig. 5.9 Distribution of seasonal precipitation quantities in the Moldavian Plain

2.2.4. The non-perodic variations of the annual precipitations quantities

From one year to another, the precipitations to fall in the narrow Moldavian Plain, display wide variation between the limits. The variability of the annual quantities and the deviations from the median values is rendered below fig. 5.18.

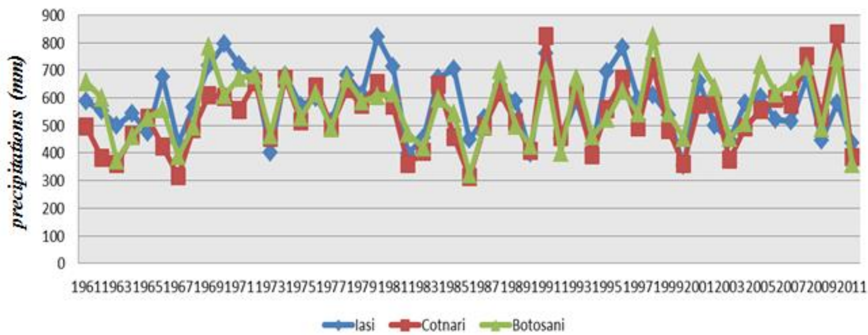


Fig. 5.18 The Moldavian Plain – Variation of the annual precipitations quantities in the 1961-2011 at Iaşi, Cotnari and Botoşani stations

The analysis of the graphic representations on the basis of the observations performed in the last 50 years (with only minor discontinuities), at 11 meteorological stations and pluviometric posts (fig. 5.19) reveals a synonymous evolution of the annual precipitations sums.

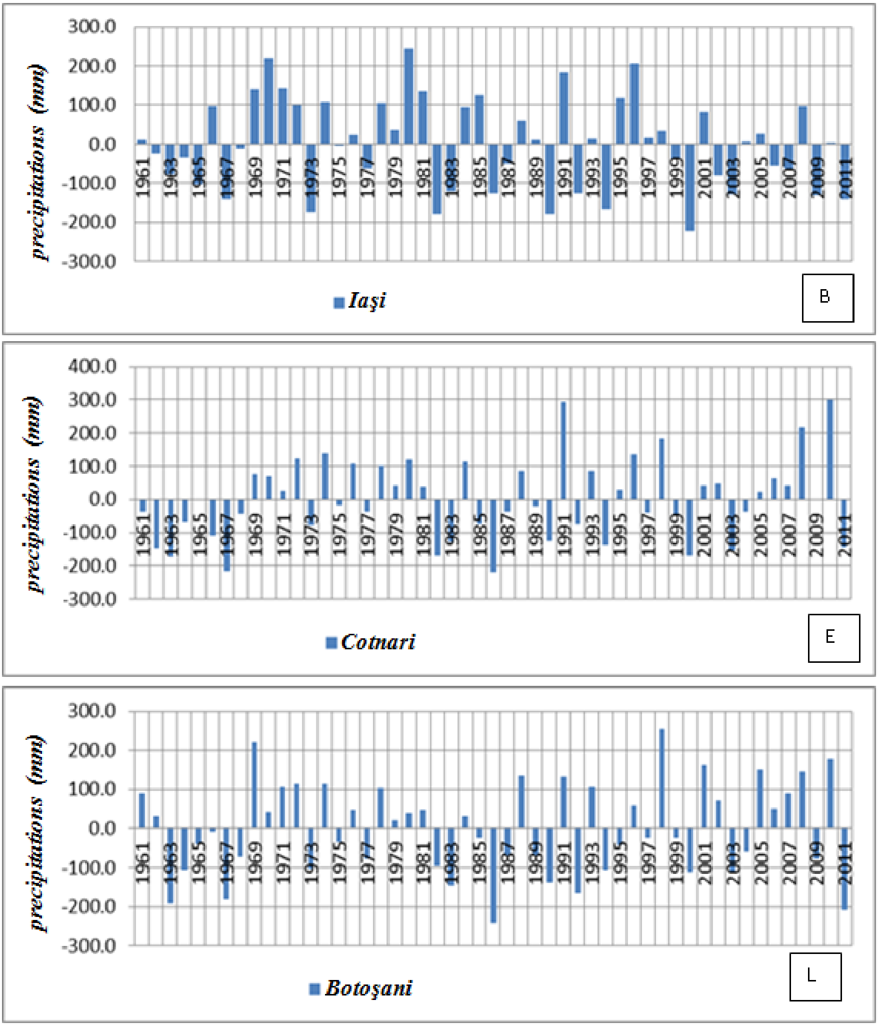


Fig. 5.19 A-N The Moldavian Plain – Deviations from the average multi-annual precipitations quantities in the 1961-2011 interval

2.2.5. The non-periodic variations of the monthly precipitations quantities

A more clear and realistic image on the monthly excesses and shortages for the analyzed period (1961 - 2011) is offered by the Hellman approach which renders the weather types on the basis of percentages monthly deviations from the multi-annual averages; this classifies the months in 9 categories from excessive to deficient concerning rain. In this way the classification of only two categories of months, as excessive and deficient is eliminated on the basis of positive and negative values reported to the average value.

As first instance, for a correct analysis and due to certain posts and stations dismantle since 1990 or setting of new post and stations (with large gap as 1961 reference) we analyzed the data on two common intervals of 30 years: 1961-1991 and 1981-2011 (fig. 5.20).

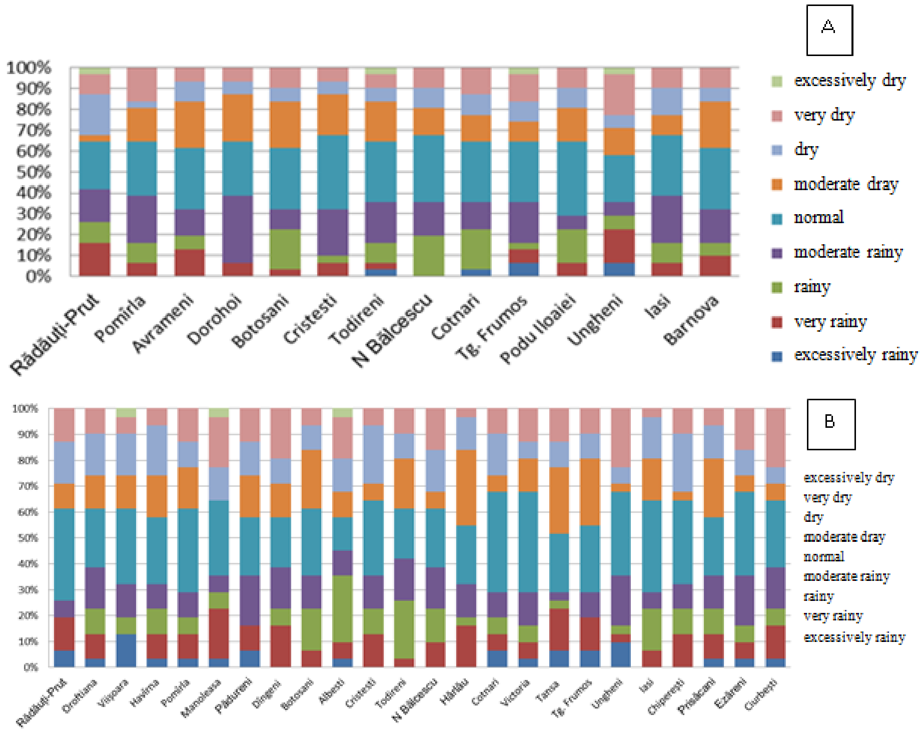
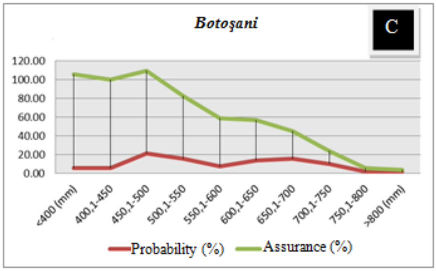


Fig. 5.20 The pluviometric characteristics based on the Hellman criterion in the Moldavian Plain for 1961-1991 (A) and 1981-2011 (B).

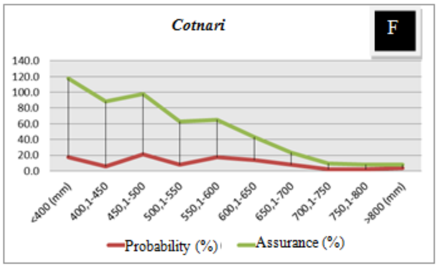
2.2.6. Precipitations' frequency in the Moldavian Plain

The frequencies values and assurance values for the monthly precipitation quantities (fig. 5.27) are expressive and include an increased trustiness and representativeness degrees given by the monthly precipitations analysis on an extended period (1961-2011).

Botosani			
Precipitations' quantities	Absolute frequency%	Relative frequency%	Assurance %
<400 (mm)	3	5.88	100.00
400,1-450	3	5.88	94.12
450,1-500	11	21.57	88.23
500,1-550	8	15.69	66.67
550,1-600	4	7.84	50.98
600,1-650	7	13.73	43.14
650,1-700	8	15.69	29.41
700,1-750	5	9.80	13.72
750,1-800	1	1.96	3.92
>800 (mm)	1	1.96	1.96
Total	51	100,0	100



Cotnari			
Precipitations' quantities	Absolute frequency	Relative frequency%	Assurance %
<400 (mm)	9	17.6	100.0
400,1-450	3	5.9	82.3
450,1-500	11	21.6	76.4
500,1-550	4	7.8	54.9
550,1-600	9	17.6	47.0
600,1-650	7	13.7	29.4
650,1-700	4	7.8	15.7
700,1-750	1	2.0	7.8
750,1-800	1	2.0	5.9
>800 (mm)	2	3.9	3.9
Total	51	100,0	



Iasi			
Precipitations' quantities	Absolute frequency	Relative frequency%	Assurance %
<400 (mm)	3	5.9	100.0
400,1-450	7	13.7	94.1
450,1-500	5	9.8	80.4
500,1-550	6	11.8	70.6
550,1-600	9	17.6	58.8
600,1-650	5	9.8	41.2
650,1-700	8	15.7	31.4
700,1-750	4	7.8	15.7
750,1-800	3	5.9	7.8
>800 (mm)	1	2.0	2.0
Total	51	100,0	

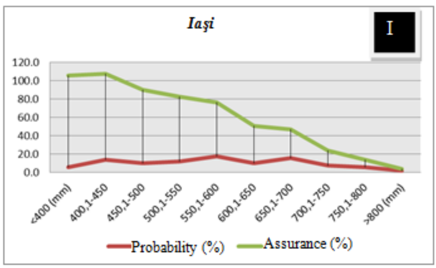


Fig. 5.27 Occurence probability and assurance degree of different precipitations quantities for the Moldavian Plain pluviometric posts(A-K) between 1961 and 2011

The maximum percentage values of the monthly sums of precipitations in January and February indicate decreased quantities, usually below the threshold of 30 mm. Toward the warm period of the year the monthly precipitations increase, where in June and July the most frequent values are between 60 and 100 mm. After this point the monthly sums of precipitations decrease progressively until October when the most frequencies are between 20 and 30 mm with a slight increase in November (10-40 mm) followed by the interval of main annually pluviometric minimum.

In general, the maximum frequency of the annual precipitations sums in the Moldavian Plain is set between the 450-600 mm quantitative limits. The annual sums increased no more than 750-800 and exceptionally over 800-850 mm, yet the probability of their occurrence maintained very low. Furthermore, a great assurance degree is given by the 300-350 mm sums interval, yet with a very low frequency.

2.2.7. Torrential rains – precipitations' duration, intensity and abundance

Torrential rains are atmospheric phenomena with short duration influence but with great intensity, upon the environment via erosion and flooding. They consist in increased precipitation quantities on short time intervals, sudden change of intensity along with extension of duration.

Torrential rains are very effective and influence the physical geographic processes along with technical works. All the norms used to evidence torrential rains refer to the fall of a high quantity of rain in a short time interval. The increase in quantity may be accompanied by increase in duration which means that for higher quantities intensity can be lower.

2.2.7.1. Precipitation's duration

Cumulatively, the average annual duration of precipitations as rain-falls, torrential showers, snow, snow-showers and drizzle between 1981-2011 was of 810 hours at Botoşani and, at Iaşi the duration exceeded Botoşani with 1200 hours. In this manner the role of urban condensation nuclei at Iaşi is once again evidenced showing the genesis of suplementary precipitations and the increase in their duration (tab. 5.6).

Table 5.6 Average monthly duration in hours and minutes of torrential rains in the Moldavian Plain for the 1991-2011 interval

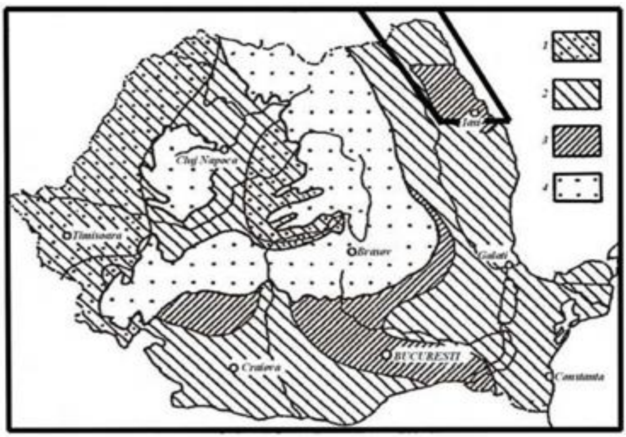
Luna	A		M		I		I		A		S		O	
Statia	**ore**	**min**	**ore**	**min**	**ore**	**min**	**ore**	**min**	**ore**	**min**	**ore**	**min**	**ore**	**min**
Botoşani	12	45	27	09	30	48	31	17	25	23	18	32	7	47
Cotnari	14	43	24	18	26	41	18	20	16	40	23	19	8	46
Iaşi	17	30	27	43	27	30	22	32	18	14	23	21	8	22

2.2.7.1. Precipitations' intensity

In the case of rains, the maximum intensities do not exceed, at any station in the Moldavian Plain, the 1,01-2,00 value interval where the intensities are closer to the lower side of the interval and, at Cotnari the maximum intensities do not exceed the 1,01 threshold value.

As far as the vulnerability of the Moldavian Plain to the suumer rains we notice that the northern half displays an intermediate vulnerability while the southern half diplays a higher vulnerability. We also notice that for the whole space east, south-east and south of the Carpathians is vulnerable to an apreciable extent to torrential rains with intermediate and high intensities. In figure 5.32 we also observe that in those areas where oceanic influences predominate, rains have a less violent character and in those areas where continental influence pedominate (as the case of the Moldavian Plain) torrentail rains have a more violent character. In the Moldavian Plain the degree of vulnerability of torrential summer rains increases from WNW to SSE. Torrential rains bring a great pluviometric input that can reach a monthly quantity of 172.1 mm in July at Botoşani and 277.2 mm in June 1985 at Iaşi. The May-September interval remains the of the greates torrential rains with high and exceptional quantities of rain.

Fig. 5.32 Romanian territory and Moldavian Plain vulnerability at torrential rains (1 - small; 2 - intermediate; 3 - big; 4 - combined) – by Octavia Bogdan et. al., 1999



2.2.7.2. Precipitations' abundance

The greatest annual value of precipitations quantities in 24 hours for the Moldavian Plain was 145,8 mm at Răuseni, on 06.09.1998 while the lowest maximum value was 75,4 mm at Dorohoi on 22.07.1974. In the same period, at Bârnova pluviometric post, on 7.09.1989 there were 167,9 mm as a result of cold air nucelus that descended from the plateau polar depression and resulted in increased weather instability between 6 and 7th of September 1989 (Sfîcă, 2007) .

2.2.8. The snow and the snow cover

In the studied zone, the snow precipitations fall early (as average) on the north-western high ridge (13-XI) and later in the south-eastern side (Moldavian Plain) (23-XI). The snow cover melt takes place, in average until 21 of March in the lowlands and until 28 of March in the highlands. In this respect the duration of snow fall as probability grows from 118 days to 135 day depending on altitude and latitude (MP).

The average thickness of the snow-cover is relatively small. It grows starting with the beginning of November (0,1 cm) until mid-February when the thickness becomes maximum (13 cm) and lowers until the beginning of April (0,5 cm).

3. The hydrographic features of the Moldavian Plain

3.1. The hydrographic network

The hydrological regime depends to a great extent on the hydrological network which constitutes an important assembly that limits the influence of the geographical factors. The dimensional characteristics of the rivers and of the source watersheds influence the volume of the received precipitations and the necessary time for main streams catchment and watershed output. These characteristics impose, finally, the volume of the liquid discharge.

3.1.1. The hydrographic network scheme

As compared to the Carpathian range the river in the present study pertain to the eastern group of the Prut hydrographic basin. On the basis of the hydrographic systems classifications that refer to tributaries' association model, for Romania, T. Morariu et. al. (1962) we conclude that the above mentioned rivers are organized in a dendritic geometry. In most of the cases the river junctions are in narrow angles and oriented to the main stream effluence direction.

Apart from of the discharge character the water courses length is 11,000 km, where 3000 km are permanent streams, approximately 6000 km are semi-permanent and almost 2000 km are intermittent streams. Amongst the Moldavian Plain rivers there is Jijia with 282.6 km, Bahlui 110.6 km, Başeu 106 km, Sitna 69.3 km, Volovăţ 52 km, Bahlueţ 50.1 km while other streams do not exceed 50 kilometres (fig. 6.5).

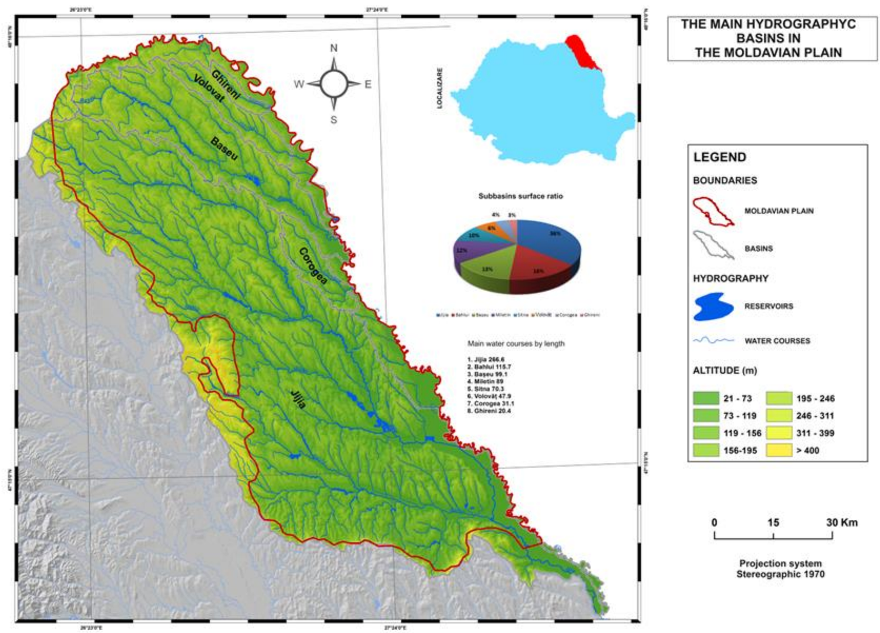


Fig. 6.5 The main hydrographic basisns in the Moldavian Plain

3.1.2. The morphometric and morphographic characterization of the hydrographic basins

3.1.2.1. The hydrographic basins surface

The surface of the hydrographic basins increases in dimension along with the river advance to the lower sectors when affluents become more numerous and new surfaces are dreained. The bigger the watershed the bigger the water discharge volumes. For example, the Bahlui river has a debit of 0.421 sq. meers/second at Hârlău (S=139 sq. km) 1.06 421 sq. meers/second at Iloaia's Bridge (S = 587 sq. km) and 3.03 421 sq. meers/second at Iaşi (S=1436 sq. km) (tab. 6.1).

As a consequence of the high degree of elongation of the watersheds as reported to their height, with 12 to 1 for Başeu and 14 to 1 for Jijia, the necessary time for waters to move from the side sub-basins to the streams thalweg (on an inclined slope) may be between 24 and 28 times smaller than the time necessary for water movement from the upper watershed to the lower one.

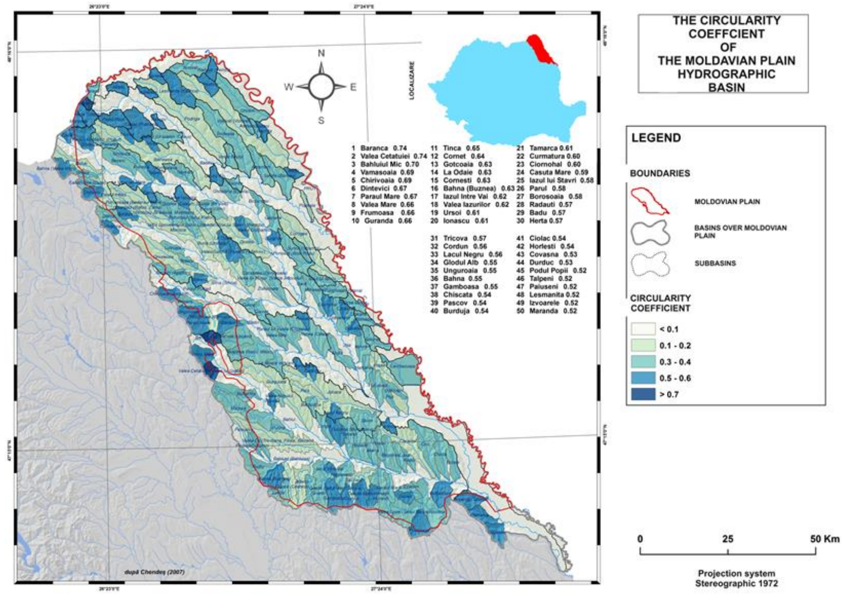


Fig. 6.8 The circularity coefficient of the Moldavian Plain hydrographic basins

3.1.2.2. Average altitudes

If we analyze the repartition of altitudinal zones as reported to the surface of the region we can understand why at the majority of hydrometric posts the average basins input altitude is around 150 meters. The average altitude, actually explains the average geographic conditions assembly where the respective hydrologic regime is described for a river at at hydrometric post and its value decreases along the river toward the lower sector (fig. 6.9).

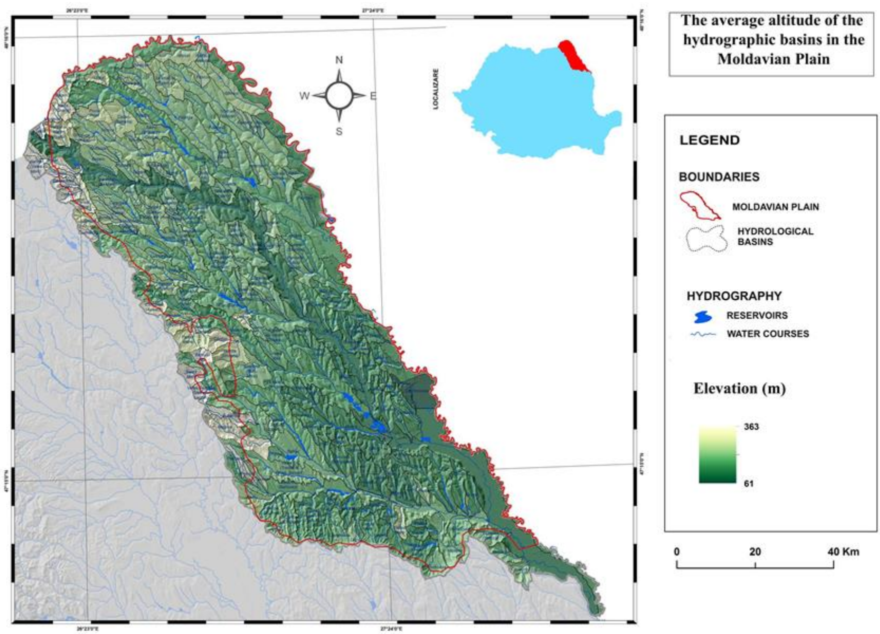


Fig. 6.9 The average altitude of the hydrographic basins in the Moldavian Plain

3.1.2.3. Hydrographic network density

When analyzing the hydrographic network density map (fig 6.10) we notice values between 0,1 and 0,7 km/km^2 for the permanent rivers in the NE of the Moldavian Plain. The highest values (over 0,50) are encompassed on the right Jijia basin and the lowest values (predominantly below 0,40) describe some small basins that are tributary to Prut River directly.

For the study zone the average density of the permanent network is 0,45 km/km^2 which is very close to the national average (0,49 km/km^2).

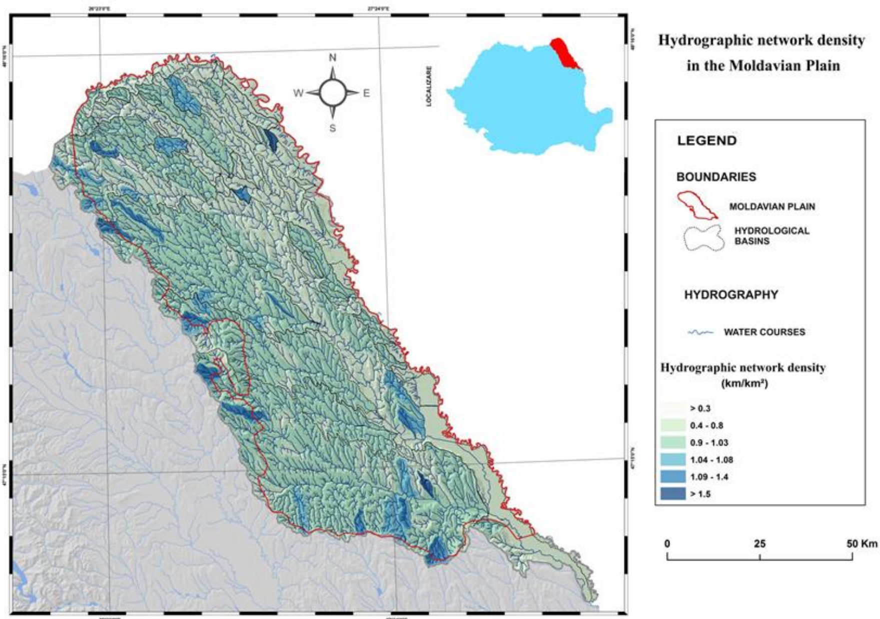


Fig. 6.10 Hydrographic network density in the Moldavian Plain

3.1.3. Types of water discharge in the Moldavian Plain

Depending on the type of discharge in the hydrographic network of the Moldavian Plain, there three aspects to be considered:

- *the permanent discharge* is specific to the rivers that develop at the limits of the Suceava Plateau, the Nicolina river in the Central Moldavian Plateau and also Volovăț, Corogea, Bahlui, Ibăneasa and the rest of first order affluents of Prut, on the right and of Jijia, on the left, in certain sectors. The permanent flow of these rivers is insured by the underground strata waters in the hills of the Moldavian Plateau and the terraces and alluvial plains of the Moldavian Plain.

- *the intermittent discharge* is characteristic for all the rivers with south-north direction on the cuesta type versants. In the frame of the excessive continental climate of the Moldavian Plain, for the NE Romania, these highly inclined versants have poor subterranean waters. On these rivers the discharge occurs only in abundant surface supply (snow melt and torrential rains).

- *the semi-permanent discharge* is representative for the rest of the hydrographic network, in fact, for almost all of the study region and is determined by the semi-permanent character of the aquifer strata. Depending on the value of the climatic elements (temperatures, precipitation and humidity) and on their repartition in different years, the underground waters of the Moldavian Plain, in the narrow interfluves and on the Sun exposed versants, become very poor, reaching the 0 value which results in discharge interruption.

On the majority of rivers in the Moldavian Plain the character of the discharge is determined by the human activities. In this category we also include the rivers that were transformed in pond chains.

3.2. The hydrologic balance

The hydrologic balance represents a method to determine the quantitative report in which the source possibilities for the water input behave according to the water output in a precisely delineated region. The hydrologic balance analysis reflects the aquatic quantitative reserves of a certain region. The spatial differentiation of the hydrologic balance is manly determined by the general decrease of air humidity from NW to SE in the study region.

For the determination of the hydrologic balance, Maria Pantazică, in the Moldavian Plain Hydrography uses the Lvovici's equation where the superficial leakage (So) added to the soil's total humidity (Wo) is considered equal to the water input from precipitations (Xo) calculated as averages of an extended period (over 20 years) (tab. 6.4):

$$X0 = Y0+Z0 = S0+U0+Z0$$

X0 –the average of annual precipitations' sums;

Y0 – the global average leakage;

Z0 – evapotranspiration;

U0 – subterranean leakage;

S0 – superficial leakage.

The total soil's humidity represents the sum of water quantity which, via infiltration, contributes to the formation of the subterranean sources leakage (Uo) and the quantity of water lost through evapotranspiration (Zo).

Table 6.4 Elements of hydrologic balance of the rivers (A.B.A. Prut-Bârlad supported data)

No.	River	Post	Hmed m.	Xo mm	Yo mm	Zo0 mm	So mm	Uo mm	Wo mm
1.	Bahlui	Iaşi	150	603	55.5	547.9	41.3	7.1	554.6
2.	Bahlui	Pd. Iloaiei	202	498	56.9	441.2	45.1	8.2	444.7
3.	Bahlui	Hârlău	317	526	96.7	429.7	79.8	6.1	440.1
4.	Miletin	N. Bălcescu	202	560	67.4	492.8	47.8	5.2	507
5.	Sitna	Todireni	167	506	78.9	427.3	44.2	7.2	454.6
6.	Sitna	Botosani	202	566	90.1	476.3	51.5	4.9	509.6
7.	Jijia	Chiperesti	155	521	69.5	447.3	37.9	6.5	476.6
8.	Jijia	Victoria	159	514	62.1	407.4	38.4	5.8	469.8
9.	Jijia	Todireni	186	503	66.0	440.1	43.8	7.6	451.6
10.	Jijia	Dorohoi	262	548	87.5	461.0	71.2	4.8	472.0
11.	Baseu	Stefanesti	168	499	56.8	441.8	37.1	6.8	455.1
12.	Volovăţ	Manoleasa	178	501	61.6	439.4	40.1	6.0	455.1

3.3. Average discharge

The average discharge of the rivers is determined by the average arithmetic value of the daily average debits, monthly average debits and annual average debits on a multi-annual period, where the average gets as stable as possible for the given physical-geographic conditions as a result of more data accumulation. The average discharge can be expressed for comparable necessities, in specific debits (l/s/km^2) or water strata (mm).

3.3.1. Average multi-annual discharge

From the resulted data analysis and from the ones, graphically represented (fig. 6.16), we notice the increase of the annual average debits from springs to effluences, as directly reported to the increase of the affluences number and, respectively to the increase of the supply basins' surfaces. For example, on Jijia, the main stream of the study region the debits are 0.67 m^3/s at Dorohoi, 2.25 m^3/s at Todireni, 6.38 m^3/s at Victoria and 12.3 at Chipereşti. The increase gradient has an average of 1.75 m^3/s at 1000 km^2.

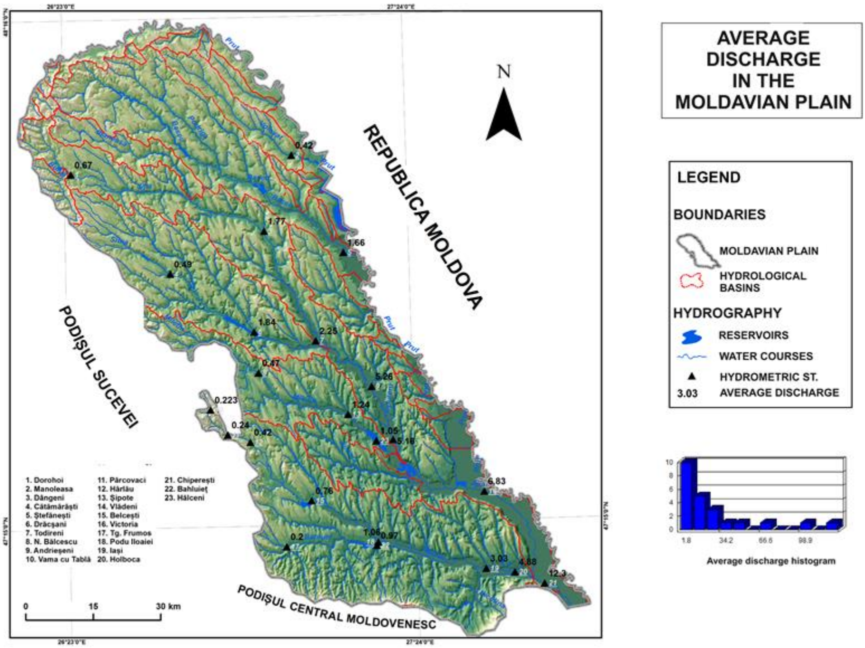


Fig. 6.16 The average rivers' debits in the Moldavian (1950-2011)

Due to the physical-geographic conditions of the supply hydrological basins, the debit's increase as reported to their unequal surfaces suffer from a high asymmetry as evidenced by the analysis of the specific debits. Thus, when reporting the debit to the corresponding surface we notice a decrease of values when basins become larger (fig. 6.17). This situation indicates the fact that, in reality, the input strength for the rivers in larger basins becomes lower because the more extended basins suffer from the excessive character of the continental climate that is less favourable for water discharge.

From year to year the average debits oscillate over a long period, especially as a function of the climatic elements variation. Thus, the variations of precipitations, which are the main source of supply for rivers and the temperatures, along with humidity variations determine the value of the debit for each year (fig. 6.18).

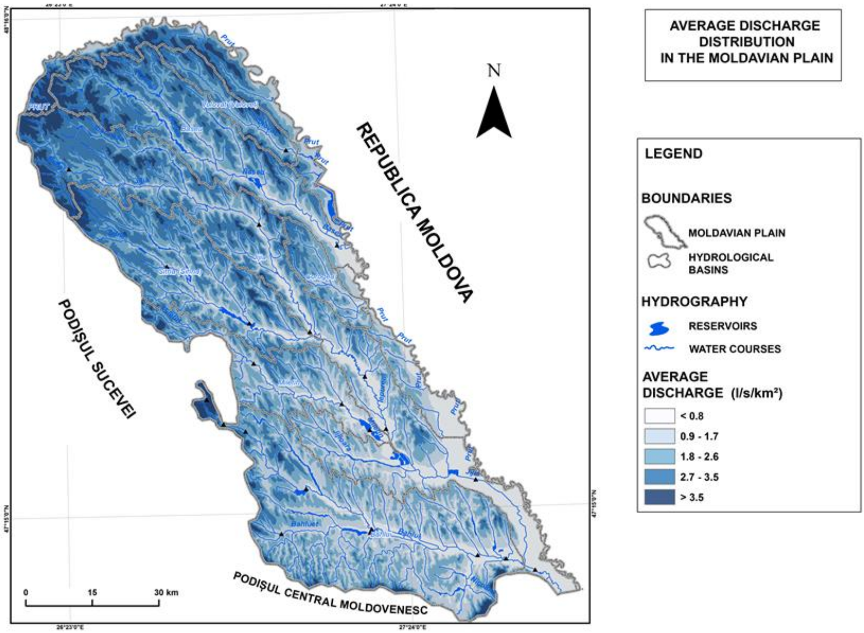


Fig. 6.17 Average discharge distribution in the Moldavia

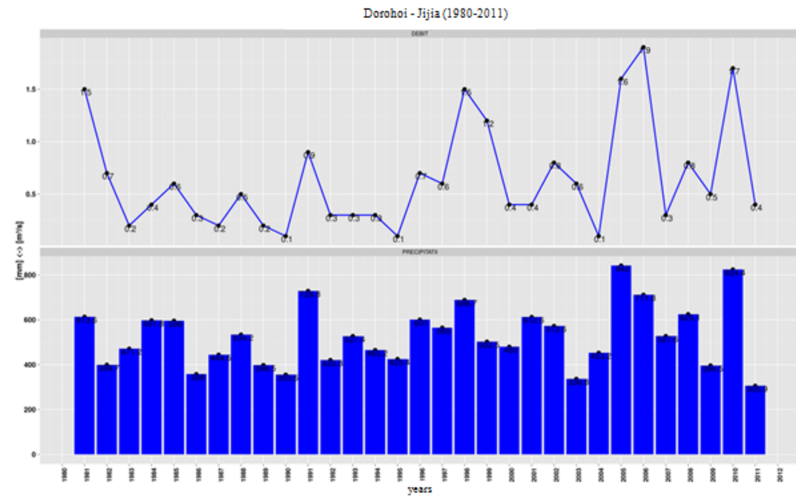


Fig. 6.18 The multi-annul variation of the average debits and precipitations in the Moldavian Plain

3.3.2. Cyclic variation of the average discharge

In order to determine the cyclic character of the discharge for the hydrometric stations in the Moldavian Plain we calculated the gliding averages on 5 years for the average values of the annual debits. By graphically transpose the results (fig. 6.19) we observe that all the hydrometric stations present two periods of increase on rivers; the first period between 1965 and 1984 and the second period between 1995 and 2010, determined by the precipitations' increase. Inside the first period we notice two important peaks in the rivers discharge corresponding to 1969 and 1982. In the same time, analysing the gliding averages on 5 years we can identify, very easily, the decrease between 1985 and 1989.

The characterization of the variability of annual debits for a certain period, as reported to the multi-annual debit is suggestively expressed via the variation coefficient (Cv).

For the rivers in NE Moldavia the values of Cv for the annual average debits oscillates between 0.07 on Bahlui, at Hârlău and 0.78 on Jijia, at Victoria. Comparing these results with the ones calculated by S. Dumitrescu (1964) for 38 characteristic points in Romania we infer that, in the main basins of the Moldavian Plain, the annual average debits are very unstable, mainly as a consequence of the excessive continental climate.

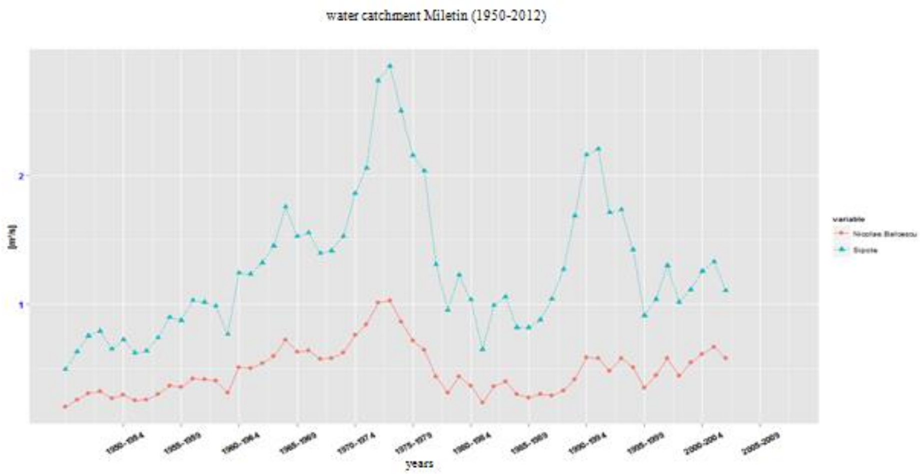


Fig. 6.19 The variation of the average debits on five years gliding averages for the main rivers in the Moldavian Plain

The characterization of the variability of annual debits for a certain period, as reported to the multi-annual debit is suggestively expressed via the variation coefficient (Cv).

For the rivers in NE Moldavia the values of Cv for the annual average debits oscillates between 0.07 on Bahlui, at Hârlău and 0.78 on Jijia, at Victoria. Comparing these results with the ones calculated by S. Dumitrescu (1964) for 38 characteristic points in Romania we infer that, in the main basins of the Moldavian Plain, the annual average debits are very unstable, mainly as a consequence of the excessive continental climate (*Fig. 6.20)*.

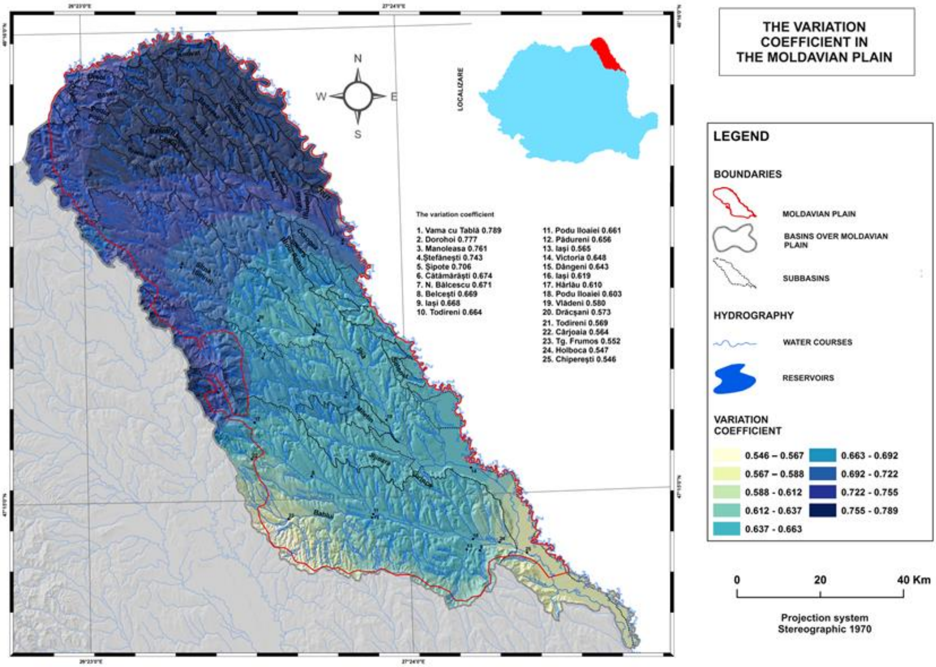


Fig. 6.20 The variation coefficient in the Moldavian Plain

3.3.3. Average seasonal discharge

At the level of the Moldavian Plain, the average seasonal discharge is higher in the spring (41%), lowers in summer (25%) and is lowest in winter (19%) and in autumn (15%) and pertains to the SSWA regime (spring-summer-winter-autumn), as defined by *Ujvari, 1972, Lăzărescu, Luca 1979, Geography of Romania, vol.I, 1983*). *I*

3.3.4. Average monthly discharge

If we analyse the average monthly discharge over the year (fig. 6.22) we notice the existence of a uniform regime for all the rivers in the Moldavian Plain.

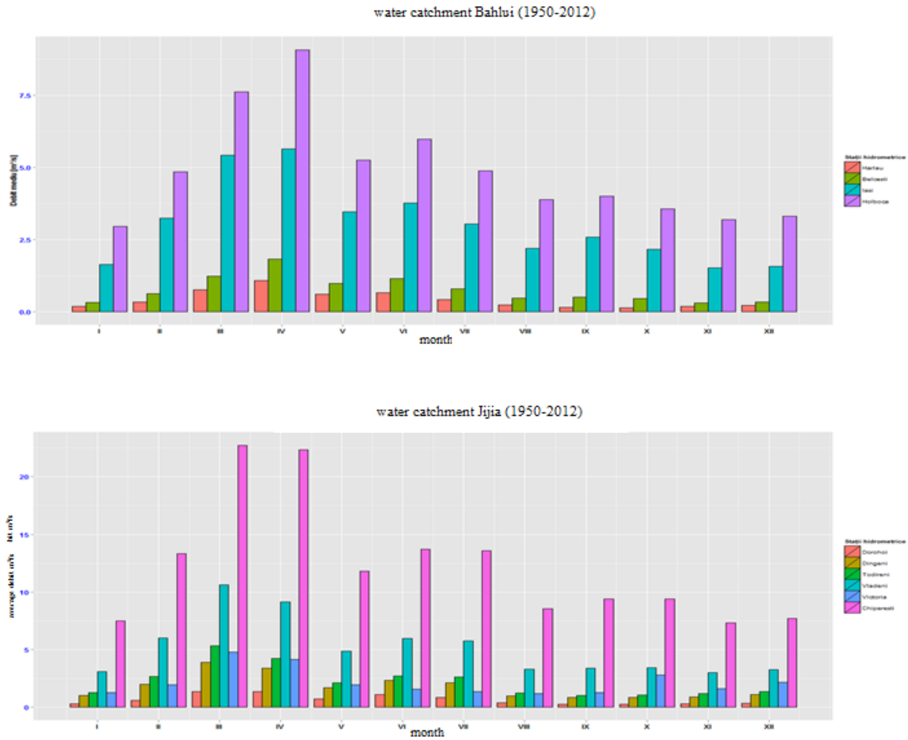


Fig. 6.22 The monthly average variation of the debits in the Moldavian Plain

If we analyse the frequency of the monthly debits for an array of years (1950-2011) (Fig. 6.23), we notice the highest frequency in the study zone is given by the 0 to 2 m^3/s debits' class (78% for Başeu at the Ştefăneşti hydrometric station, over 90% on Volovăţ, at Manoleasa, on Sitna at Cătămărăşti, on Miletin at Nicolae Bălcescu, on Bahlui at Hârlău and on Jijia at Dorohoi).

The 2-4 m^3/s debit class is second as importance (25% on Bahlui at Iaşi and on Jijia at Victoria hydrometric station).

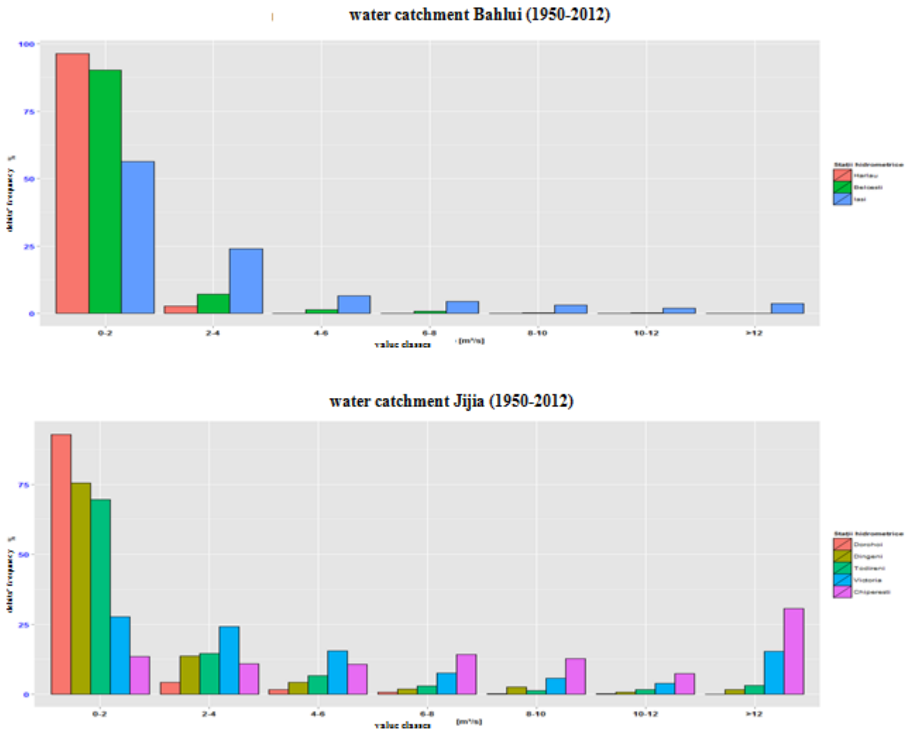


Fig. 6.23 The monthly debits' frequency at the Moldavian Plains' hydrometric stations.

The lowest frequencies for the monthly average debits are those of 12 m^3/s which have a maximum value of 30% on Jijia at Chiepereşti but these debits are occasional. Even if these kind of values have, in a usual regime, have increased frequencies at the downstream stations, due to anthropic intervention (water accumulations) the situation is changed. For example, on Bahlueţ at Târgu Frumos there are average debits of over 12 m^3/s more frequent than at Iloaia's Bridge (Fig. 6.24).

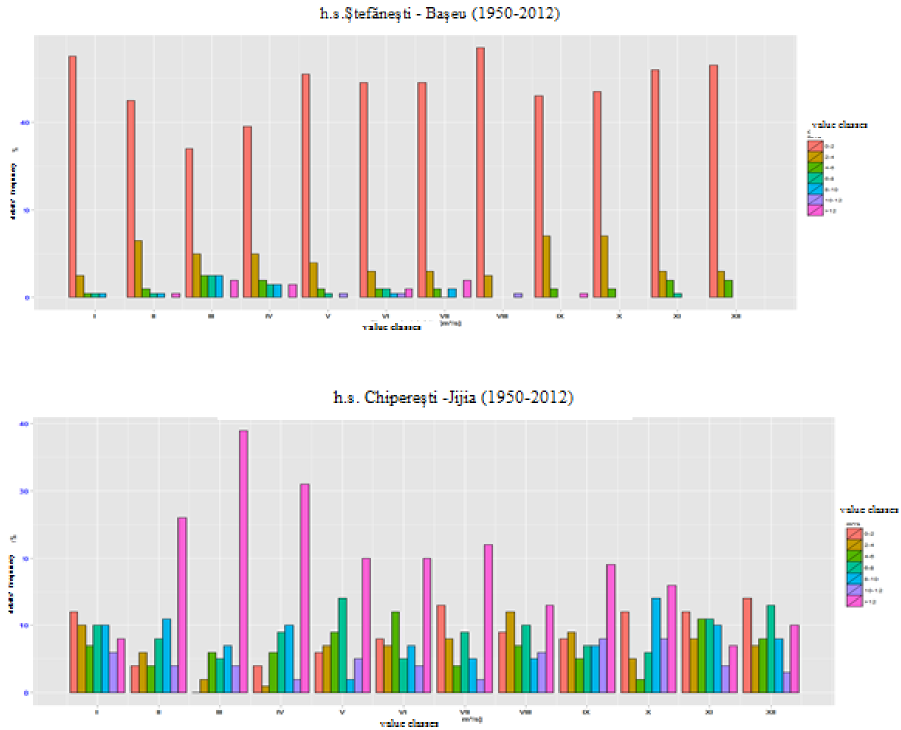


Fig. 6.24 The monthly debits' frequency on value classes at the main hydrometric stations in the Moldavian Plain

3.4. The maximum discharge and the associated risks

An important characteristic of the Romanian rivers discharge regime is the presence, all along the year, of high debits periods that are induced either by the very abundant atmospheric precipitations or by snow melt or by these two phenomena combined.

3.4.1. Maximum multi-annual discharge

The statistical analysis of maximum discharge at the level of the Moldavian Plain is performed on the data recorded at the main hydrometric stations between 1950 and 2011. This analysis allows the extraction of practical information which may lead to the implementation of measures in the projection phases, the execution phases and the exploitation of hydrotechnical constructions in order to diminish the effects of hydrological hazards, especially in the vulnerable zones.

The most representative parameters of the maximum discharge to be analysed refer to the maximum debits (overflows) and the maximum volumes associated, as well as the floods and inundations.

Due to the fact that the hydrometric stations were not put in place in the same time there are differences in recorded data of the historical maximum overflows as it is shown in tables 6.7 and 6.8.

As mentioned above, the statistical analysis of the maximum debits and volumes recorded at the hydrometric stations in the Moldavian Plain is performed for the 1950-2011 period. The multi-annual variability of the maximum overflows reveals that, at the level of the study area, there are a series of years with the highest debits (1954, 1969, 1975, 1980, 2008, 2010) and a series of years with low maximum debits (1959, 1963, 1964, 1986). A detailed analysis of the values of the monthly maximum debits recorded at the main pluviometric post and stations indicate certain spatial differences as generated by local conditions and the pluvial-thermic conditions of the occurrence period (fig. 6.31).

Table 6.7 Maximum discharge records at the hydrometric station of the Moldavian Plain

Nr crt	River	Hydro station	Q mc/s	Occurrence date
1	Prut	Radauti	4240	28.VII.2008
2	Prut	Stanca	1050	31.VII.2008
3	Prut	Ungheni	731	19.VII.1969
			710	13.VIII.1991
4	Prut	Prisacani	755	12,13.VIII.1991
5	Volovat	Manoleasa	69.0	5.VI.1988
6	Baseu	Stefanesti	330	14.VIII1969
			100	25.VII.1973
7	Jijia	Dorohoi	170	13.VII.1969
8	Jijia	Dangeni	346	14.VII.1969
9	Jijia	Todireni	394	14.VII.1969
10	Jijia	Vladeni	199	20,21.VI.1985
11	Jijia	Victoria	325	18.VII.1969
12	Jijia	Chiperesti	185	23.V.1985
13	Buhai	Padureni	96.0	20.VIII.1998
14	Drislea	Drislea	57.8	23.VII.2008
15	Sitna	Botosani	76.9	10.VI.1969
16	Sitna	Catamarasti	11.2	5.VI.2006
17	Sitna	Dracsani	101	9.IV.1979
18	Sitna	Todireni	290	10.VI.1965
19	Miletin	N Balcescu	87.1	19.IV.1969
20	Miletin	Sipote	204	19.VI.1985
21	Miletin	Halceni av	40.4	3.IV.1996
22	Bahlui	Vama cu Tabla	59.9	24.VII.2008
23	Bahlui	Parcovaci av	24.4	25.VII.2008
24	Bahlui	Harlau	119	2.VII.1971
			42.4	25.VII.2008
25	Bahlui	Belcesti	152	9,10.IV.1979
26	Bahlui	Podu Iloaiei	125	13.VII.1969
27	Bahlui	Iasi	182	9.VI.1975
28	Bahlui	Holboca	61.3	8.V.2005
29	Magura	Carjoaia	83.1	25.VII.2008
30	Bahluet	Tg. Frumos	95.0	24.VII.2008
31	Bahluet	Podu Iloaiei	18.3	3.VIII.1991
32	Voinesti	Cucuteni	8.80	10.V.2005
33	Nicolina	Iasi	92.5	27.IV.1963

Tablel 6.8 Maximum rates records at the hydrometric stations of the Moldavian Plain

Nr crt	River	Hydro station	H max	Occurrence date
1	Prut	Oroftiana	867	7/26/2008
2	Prut	Radauti Prut	1230	7/28/2008
3	Prut	Stanca av.	612	7/31/2008
4	Prut	Ungheni	754	8/13/1991
5	Prut	Prisacani	722	6/10/1988
10	Volovat	Manoleasa	410	6/5/1988
11	Baseu	Stefanesti	425	4/11/1979
12	Jijia	Dorohoi	780	6/5/2006
13	Jijia	Dangeni	619	7/14/2000
14	Jijia	Todireni	519	8/22/2005
15	Jijia	Andrieseni	560	1/30/2002
16	Jijia	Vladeni	478	8/23/2005
17	Jijia	Victoria	598	6/9/1988
18	Jijia	Chiperesti	533	6/10/1988
19	Buhai	Padureni	530	7/1/1991
20	Drislea	Drislea	224	4/23/2008
21	Sitna	Catamarasti	250	8/19/2005
22	Sitna	Dracsani	448	8/3/1991
23	Sitna	Todireni	504	6/19/1985
24	Miletin	N. Balcescu	406	8/16/1979
25	Miletin	Sipote	530	6/19/1985
26	Miletin	Halceni	321	7/5/1991
27	Bahlui	Vama cu Tabla		
28	Bahlui	Parcovaci av	234	7/25/2008
29	Bahlui	Harlau	694	7/25/2008
30	Bahlui	Belcesti	530	4/9/1979
31	Bahlui	Podu Iloaiei	456	6/8/1975
32	Bahlui	Iasi	468	6/19/1985
33	Bahlui	Holboca	411	6/19/1985
34	Maagura	Carjoaia	246	6/17/1992
35	Bahluiet	Tg. Frumos	497	6/7/1975
36	Bahluiet	Pd.Iloaie	xxx	1975
37	Voinesti	Cucuteni	213	3/6/1988
38	Nicolina	Iasi	476	4/27/1963
39	Locii	Ciurbesti	333	6/3/1988
40	Ciric	Iasi	170	11/5/2005
41	Vamesoaia	Iasi	350	7/21/1974

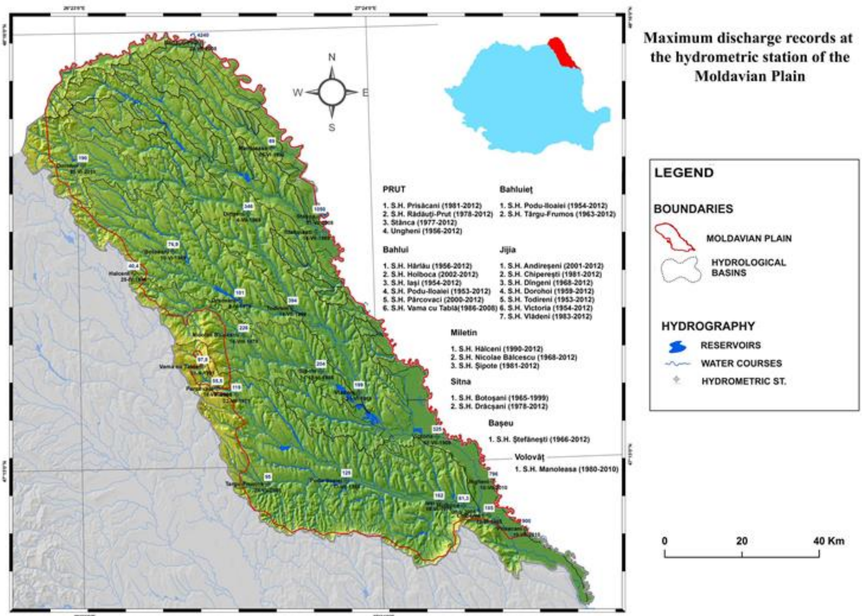


Fig. 6.31Maximum multi-annual debits in the Moldavian Plain hydrographic basin

For the Volovăţ hydrographic basin the maximum debits, at the Manoleasa hydrometric station, are recorded in 1980. The maximum maximorum is recorded on 05.06.1988 when the discharge was 69 m^3/s. Very high debits were recorded in 2010 (31.9 m^3/s), 2003 (29.9 m^3/s), 2000 (26.3 m^3/s) (fig. 6.33).

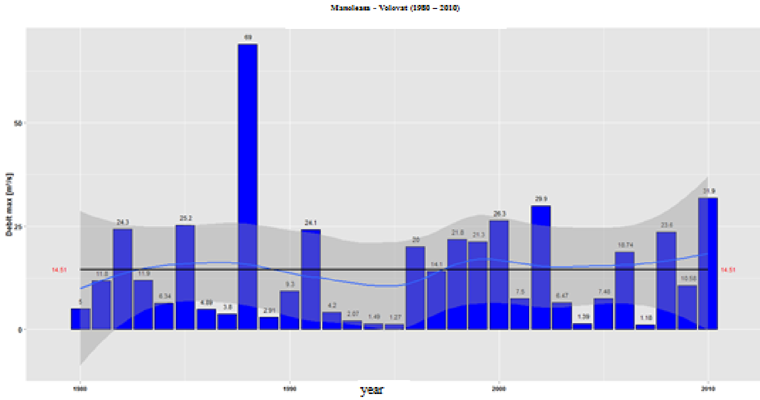


Fig. 6.33 The annual maximum debits at the Manoleasa hydrometric station, Volovăţ River

In the Jijia hydrographic basin the highest debits occurred in the spring of 1932. Even if indirectly determined these debits were 492 m^3/s at Victoria on Jijia River and 440 m^3/s at Iaşi, on Bahlui River (Pantazică, 1974). The debits were not directly recorded but the descriptions and the photographs of the event show the amplitude and the important losses that occurred as conclusive.

“From the sky enemy, it rains over the city, all the rains of the centuries. The pouring that comes from the Ioloaia’s Bridge had sunken all the lower part of Iaşi. On the Red Bridge no tram is crossing. The rain falls and the pouring is growing. At night, cavalry squadrons are sent in the lowland quarters to wake-up the citizens and evacuate the houses. The women cry, the children scream and the men curse” *Water Towers*, Sandu Teleajen (fig. 6.34).

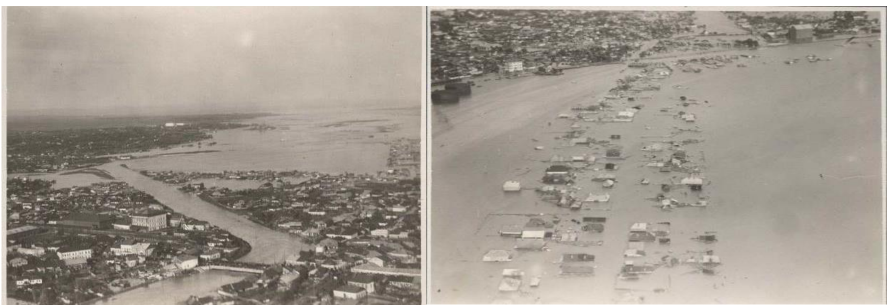


Fig. 6.34 Inundations in Iaşi, 1932 (National Archives photos)

For the 1950-2011 period the highest debits were recorded in 1969. In the summer of 1969, more precisely between 12th of July and 3rd of August, in the Moldavian Plain extremely abundant precipitations were recorded (locally over 100 mm/24 hours) which resulted in strong floods on every water course. The maximum overflow measured on the main water course in the Moldavian Plain was 394 m^3/s on the 14th of July at the Todireni hydrometric station. In the same time a maximum debit of 170 m^3/s was recorded upstream the Dorohoi hydrometric station (13th of July) and 325 m^3/s (downstream on 18th of July 1969, at the Victoria hydrometric station) (fig. 6.35). In the Bahlui hydrographic basin, the main Jijia affluent, the highest debit recorded in this period was 182.0 m^3/s, on 9th of June 1975, as a result of torrential rains in the south-eastern Moldavian Plain with 46.0 l/m^2, at the Iaşi meteorological station, 75.8 l/m^2 at Iloaia's Bridge, 48.5 l/m^2 at Strunga and 57.4 at the Cotnari meteorological station.

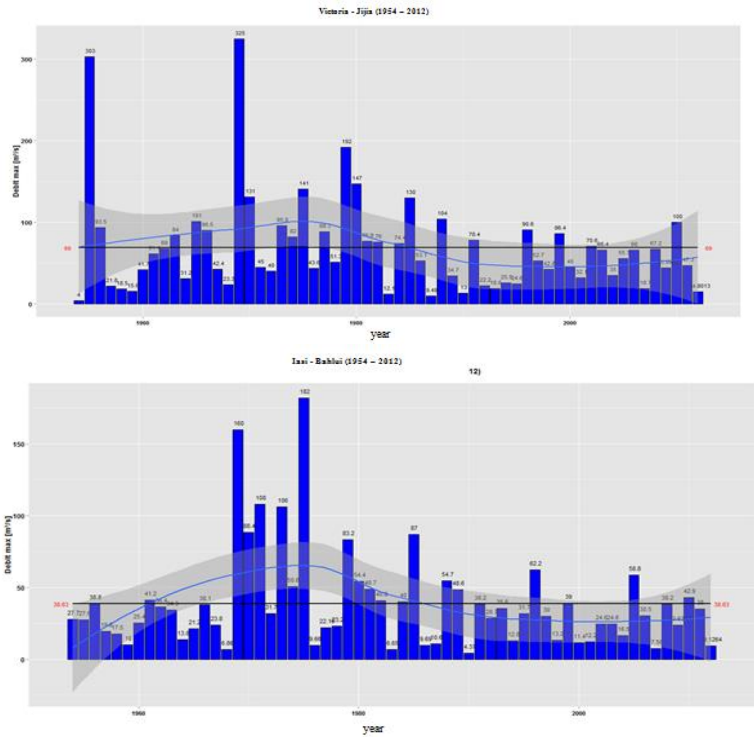


Fig. 6.35 The maximum annual debit at the Jijia hydrometric station

One important aspect as far as the maximum debits analysis is concerned is their manifestation condition with respect to the realization of hydrotechnical works (dams, accumulations, embankments, polders or river regulation). Thus, if one analyses the values of maximum recorded it is obvious that the middle and lower hydrometric stations, beginning with the sixties and the seventies, the general tendency is of reduction of these maximum debits values (the period corresponds with the intensification of the hydrotechnical works interval). Consequently, on Bahlueţ, at the Iloaia's Bridge hydrometric station, in two distinct periods 1950-1964 and 1965-2011, depending on the period of accumulation construction (1964) we notice that the average value of the maximum debits lowers from 16.4 m^3/s, in the first period to 10.2 m^3/s, in the second period.

3.4.2. Maximum annual discharge

Along the year, the maximum debits present larger or narrower variations from one month to another as a result of the pluviometric particularities. At the level of the Moldavian Plain, the maximum debits occur, more frequently, in the May-July interval (40% of the cases), followed by the March-April interval (30% of the cases). The month of June holds a percentage of 20 in the Upper Jijia Plain and 19 in the Lower Jijia Plain (fig. 6.41).

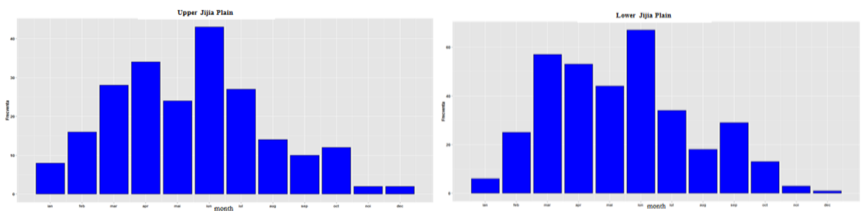


Fig. 6.41 Monthly maximum debits variation in the Moldavian Plain

The lower values of the maximum debits were recorded in the winter time (December-February), at the end of summer and at the beginning of autumn. (August-October), fig. 6.42.

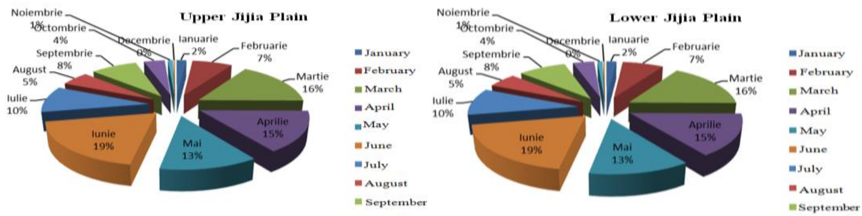


Fig. 6.42 The percentage monthly variation for the maximum debits in the Moldavian Plain

In order to project and construct the hydrotechnical works and for a more efficient management of the water resources within a hydrographic basin, it is necessary to calculate the maximum debits with certain overspill probabilities.

3.4.3. Hydrological risks associated with maximum discharge, flash floods and inundations

The most important floods in the Moldavian Plain in the 1960-2011 interval, occurred, usually in the summer, between June and July (fig. 6.43). In the above mentioned period important floods took place in the following years: 1961, 1965, 1969, 1970, 1973, 1974, 1978, 1979, 1980, 1981, 1985, 1988, 1989, 1991, 1993, 1996, 2005, 2008 and 2010 with certain differentiations according to the local conditions.

As far as the floods' average duration is concerned we notice that, on the rivers inside the Moldavian Plain, they rarely exceed 4 days, most of them lasting one day or two. In return, on the main collector, the rut River the floods' duration extends on several days and displaying the backwaters phenomenon with an extended pressure on the hydrotechnical works meant to defence against inundations. The highest number of floods occurred on the inside rivers, respectively 62.9% and only 27.1% on Prut. Between 2000 and 2011, according to the data of the Prut-Bârlad Basinal Administration, there were 130 floods in the Moldavian Plain with maximum debits that exceeded the 20% overspill probability.

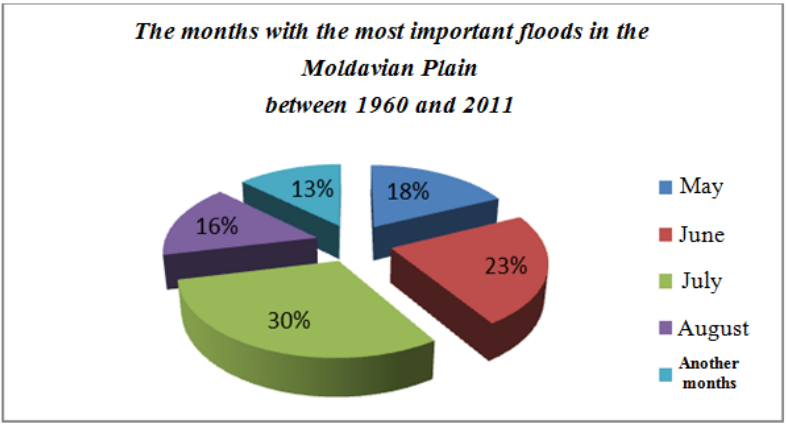


Fig. 6.43 The months with the most important floods in the Moldavian Plain between 1960 and 2011

3.5. Inundations in the Moldavian Plain

After the analysis of climatic data between 1960 and 2011 we notice that the inundations regime in the region is controlled by the water resulted from snow melt and from ice accumulations during spring (for the last years) while there is an intercalated situation with the abundant summer rains (in other recent years). Consequently, most of the inundations occur between late spring and early autumn. Nevertheless, cases where summer inundations were present along with persistent drought during late spring are numerous. The analysis of inundations recorded between 1981 and 2011 reveals 187 events, most of them cause by:

- flashlight inundations on versants that affect vulnerable communities;
- prolonged inundations on main water courses and confluences due to marsh-stagnant effect in depression zones;
- rapid floods due to rapid flow and of complex terrain model

Referring to the causes that conducted to inundations in the Moldavian Plain between 1991 and 2011 we notice 79 overspills of water course, 62 from versant leakages only and 46 mix overspills. We add to this the events on Prut and the losses for the last 30 years are shown in table 6.14.

Table 6.14 Losses induced by rivers outrush and versants discharge in the Moldavian Plain between 1981 and 2011 (data of A.B.A. Prut-Barlad and ISU Botosani and Iasi)

No.	Inflicted losses	Units of measure
1	Human lives losses	27
2	Number of affected houses, from which:	8549
3	- destroyed	1437
4	- partially affected	7112
5	Number of household annexes	4679
6	Number of social-economical objectives	584
7	Number of bridges and crosses	1621
8	Km DN	279
9	Km DJ + DC	3023
10	Km roads	74
11	Km forestry road	87
12	Ha agricultural terrain	210623
13	Forestry fond	1209
14	Km water supply pipes	17
15	Nr. affected wells	5237
16	Dead animals	3693
17	Dead birds	8610
18	Number of hydrotechnical works	107
19	Electrical networks	2492
20	Road-side channels	11
21	Cars	87
22	Roofs' rain evacuation plots	47

3.5.1. Management of inundations risks in the Moldavian Plain

Inundations and especially big inundations constitute one of the natural phenomenons that marked and are still marking the development of human society.

3.5.1.1. Inundations risks' identification, hazard and risk analysis and evaluation on hazard and risk maps

On the background of climatic changes manifested at global level, in the last years there have been an increase of extreme events frequency. The rapid alternation between abundant precipitations and inundations, severe heats and pronounced droughts and triggered major effects upon economy and social life (human lives losses and important goods losses). The evolution and the tendencies in this phenomenon production and, moreover, its consequences impose changes in the approaching manner for risk inundations' management, going from prevention and protection to effects diminishing actions.

The hazard maps and the risk maps for inundations represent an important source of information that is necessary for communitarian purposes for the identification of risks, their analysis and evaluation, their treatment and monitoring and for their re-evaluation for the purpose of effects reduction.

The hazard maps

The hazard is defined as the probability of a phenomenon appearance, phenomenon that can generate potential losses in a certain period of time for a certain zone. The elements exposed to hazard are: the population, the buildings, the engineerical works, the economic activities, the public services and the infrastructure.

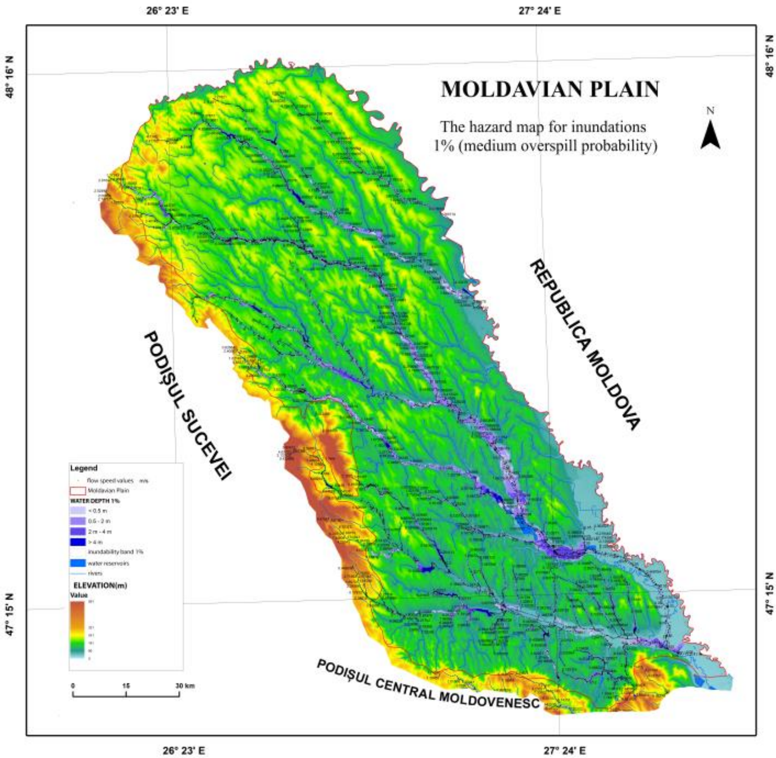


Fig. 6.44 The hazard map for inundations 1%

The hazard map for inundations constitutes the document used to express the extension of the potential floodable zones in the major river bed sectors (including depths) for floods which record the maximum debits at certain probabilities: 0.1% (low overspill probability), 1% (medium overspill probability) and 10% (high overspill probability).

The hazard map is meant to support the decisional frame, the flood management plans elaboration and the public awareness. The hazard map warns against possible inundations in for those areas, near rivers, that are exposed to flood risks. This map does not offer a high precision degree for the projection and planning of flood control constructions, especially those of industrial type, roads, water treatment stations or other. The flood hazard map incorporates, for each overspill probability, the limit of the flood (the water extension for each simulated case), the depth and the water level and the leakage speed.

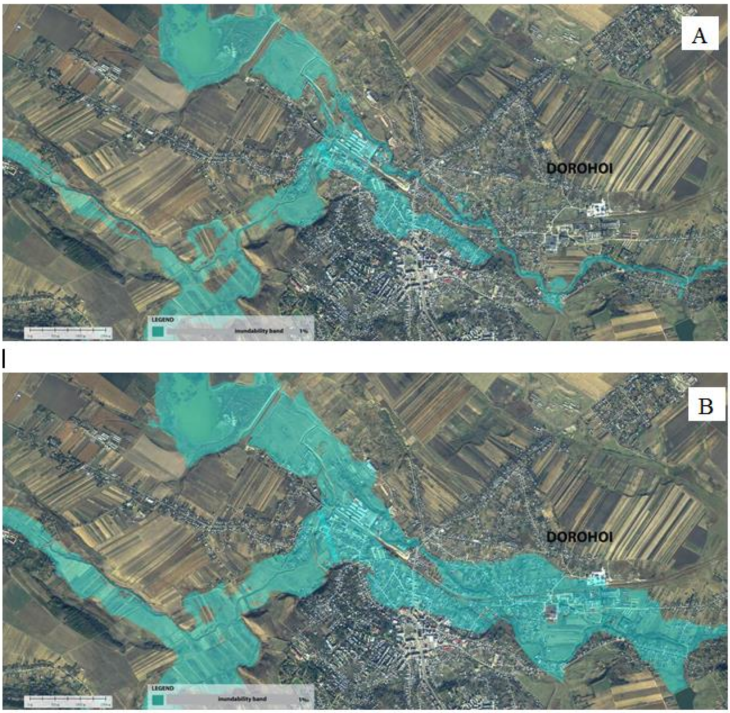


Fig. 6.45 Map extract – inundability band 1% (A); inundability band 1‰ (B) Jijia river, Mun. Dorohoi

The risk maps

The inundation risk represents the report between the probability of inundations appearance probability and the potential negative effects for human health, environment, cultural patrimony and the economic activity that are associated with inundations. The risk can be expressed as a product of hazard (probability) and consequences, which are dependent upon exposure degree, vulnerability and value. In order to dispose of applicable results, in practice, one must consider that there is no generally adequate method to be used for a specific country, a specific hydrographic basin that would measure the vulnerability with the same precision degree, thus, the vulnerability is different from the geographic and social points of view.

Fig. 6.46 The hazard map for inundations 1%

The risk map for inundations incorporates, mainly, the delineation of the following zones:

- Zones where the imposing of interdiction for permanent buildings is required, where the inundations frequency, the water depth and speed and the inundations duration result in high waters leakage
- Built zones which present a major risk for inundations, zones that are prone to be defended via structural and non-structural measures according to the *National Strategy for the Management of Inundations Risks on Medium and Long Terms.*

The elaboration of inundations risk maps in the Moldavian Plain is based on the hazard maps for inundations and on the hazard exposed elements analysis, along with their associated vulnerabilities.

The risk evaluation is realized through an intersection between the following elements:

- The risk zones (low, medium, high) generated from the floodable bands using the flood magnitude

The vulnerable parameters to inundations (population, economic activities, water supply).

The inundation risk maps allow the insertion of certain measures categories in order to prevent flood production and to minimize inundations effects, mainly through:

• the control of land use

• restrictions and, by case, interdictions of constructions location or land use, dependent on the land use category and imposing limits for inundations risks

• insertion of structural measures (dams, barriers and wetland zones) and of non-structural measures (control of the minor bed use, elaboration on the basinal management plan, warning systems and alarms) as the cases require

• elaboration of programs for material insurances and people insurances in case of inundations

• monitoring of inundations for prognosis and warning systems;

• wise allocation of funds for the application of measures that minimize inundations risks;

• elaboration of flood control plans.

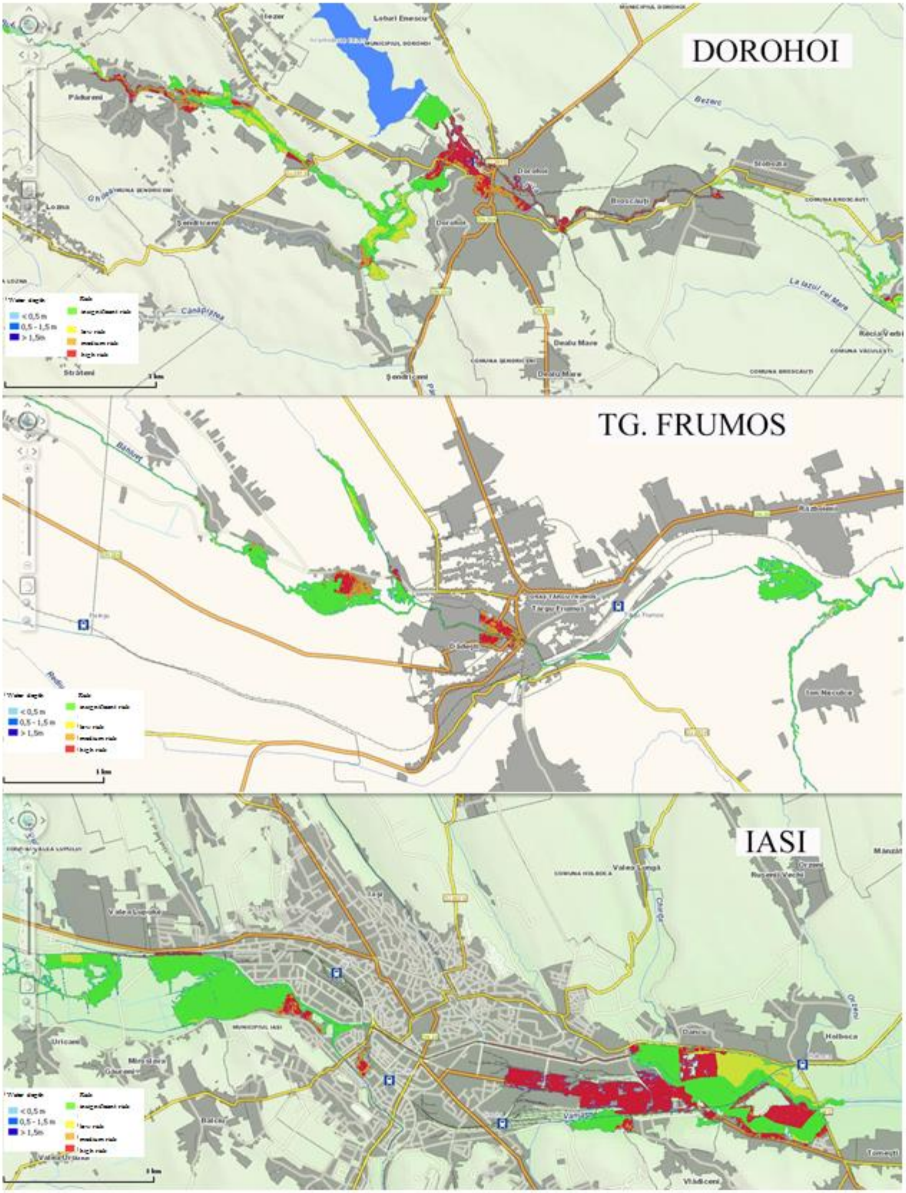


Fig. 6.47 Extracts from the inundations risk map (1%)for three settlements in the Moldavian Plain

On the basis of GIS spatial analysis the intersections of floodable bands for (with different probabilities) and the contours of localities in the Moldavian Plain we identify the potentially vulnerable localities at floods. Furthermore, these intersections can lead to estimations of inhabitant's numbers that are vulnerable to floods for each locality. For this calculus we start from the inhabitant's total number per each settlement and uniform distribution of inhabitants inside the localities limits. In conclusion, from the total number of inhabitants 1 000 286 for the Moldavian Plain, 29 237 are prone to be affected by floods with 1% probability fig. 6.63.

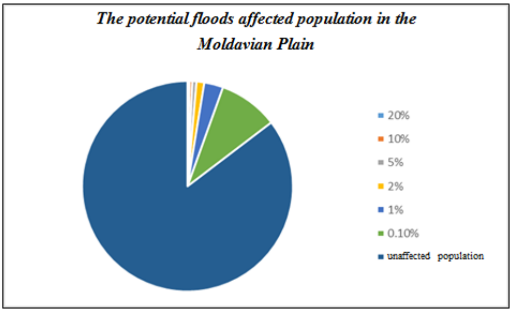


Fig. 6.63 The potential floods affected population in the Moldavian Plain

3.5.1.2. Flash floods bias conditions and inundations in small watersheds

To preliminary sort the flash floods susceptible basins, based on the Physic-geographic method, uses the elements revealed by the GIS mapping analysis (in digital format) for the Moldavian Plain and contains:

- The sub-basins map (up to the 6th order with maximum 200 km^2 surfaces);
- Land use map
- Soil map

The hydrologic groups of soils are widely used in the United States of America as major influence factor for the leakage for the most hydrological models. The soil classification prompts the evidence of the soils leakage potential. Dependent upon the texture (clay, silt or sand proportions) the soils are classified in four hydrological groups: A, B, C, D. Group A consists in coarse texture soils with the lowest leakage potential while group D with fine texture (clay) have the maximum leakage potential and, respectively minimum infiltration.

The Romanian system of texture classification is identical with USA's system, this classification being adapted to the Romanian conditions (Cehndeş 2007) and based on the ICPA textural practices (fig. 6.68).

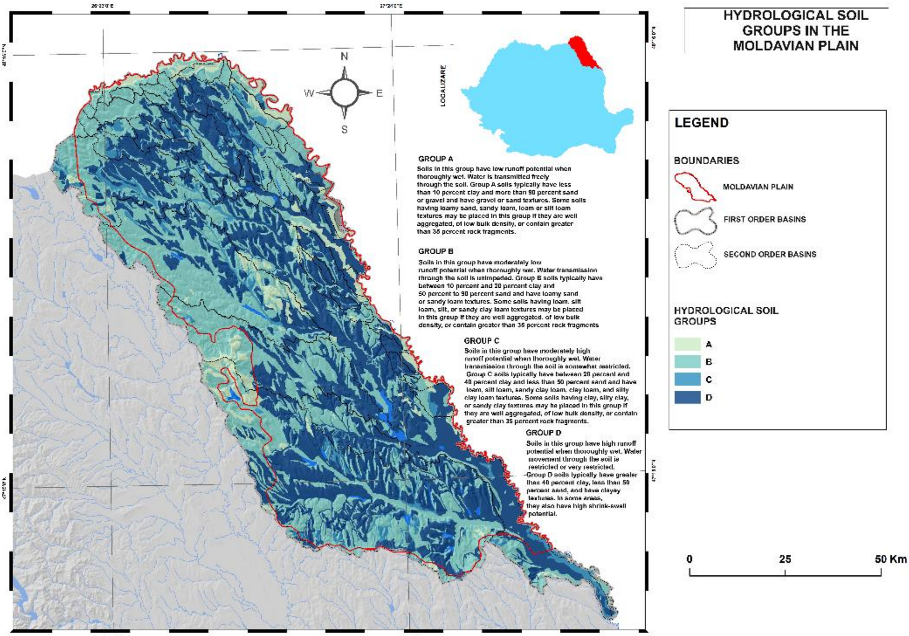


Fig. 6.68 Hydrological soil groups in the Moldavian Plain

By superimposing the layers mentioned above we obtain the digital map of the CN index (Curve Number) from the SCS model. CN (Curve Number) is a dimensionless index which can take values between 0 and 100. CN depends on the land use and on the soil's hydrological group and reflects the leakage potential for water for various terrains. The values of CN vary in direct proportion with the leakage potential and in inverse proportion with infiltration coefficient; it takes maximum values for the D soils group or in urban surfaces that are impermeable. The classification and the values assigned for the CN were adapted and realized (Chendeş 2007) on the basis of USDA manuals and on the basis of other classifications that exists in the international specialized literature. To establish the values that are specific for Romania we the Corine Land Cover 2000 were used (realized for Romania at INCD Danube Delta – Tulcea). For a given basin the global CN index is obtained as a balanced average with the partial surfaces F_i which are characteristic to the CN_i index (fig. 6.69)

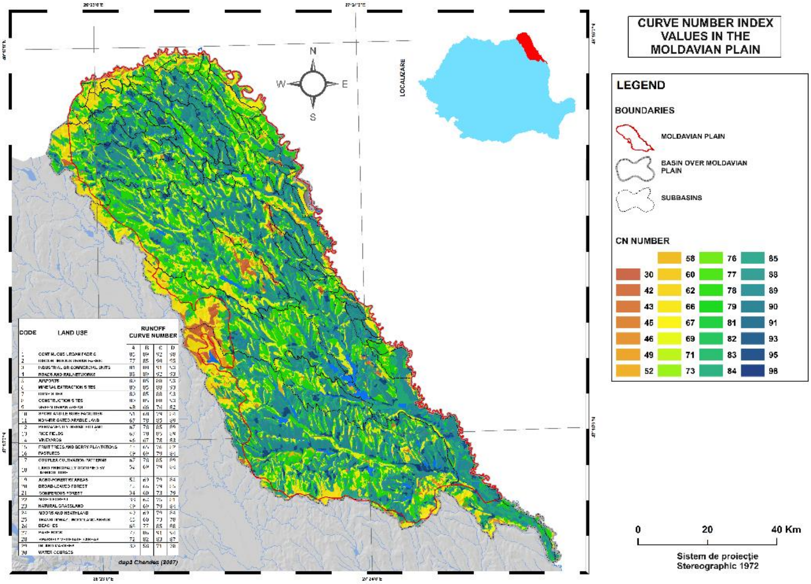


Fig. 6.69 Curve Number index values in the Moldavian Plain

On the basis of the above map the time of concentration according to the diagramme is calculated figure 6.70:

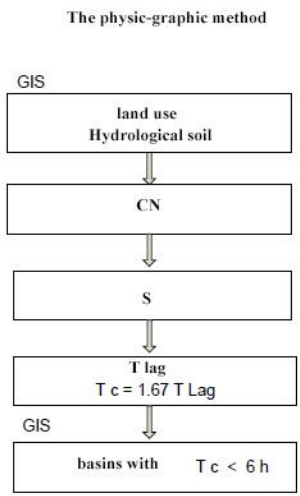


Fig. 6.70The physic-graphic method for the identification of the flash floods susceptible basins

After the CN retrieval the storage capacity is calculated, according to following relation:

$S = 25{,}4\ (1000/\ CN - 10)$

On the basis of these elements the delay time is determined T_L (T-lag), defined as the time that passes between the rain's interval centre and the moment when flood peak appears with the following relation (US Department of Agriculture, 1997):

$$T_{LAG} = (3{,}28084 * L)^{0{,}8} * \frac{(S+1)^{0{,}7}}{1900\sqrt{I_B}}$$

where:

T_L – delay time in hours;

L – the length of the main river bed in meters;

I_B – basin's average inclination in %.

Based on the delay time the concentration time is calculated (defined as the longest time for a drop of water which reaches the basin to arrive at the effluence or the time that passes between the end of the rain and the appearance of the inflection point on the descendent curve of the hydrograph) with the following relation:

$T_C = 1{,}67\ T_L$

The basins are identified with $T_C \leq 6$ hours by superimposing over the stratum that contains the human settlements which includes the spatial distribution of the CT (concentration time) sub-basins shorter than 6 hours that generates a new stratum which indicates those settlements in the Jijia basin that are susceptible of flash floods (fig. 6.71).

As a result of flash floods susceptible generator basins sorting via the physic-graphic method we identified 73 sub-basins, of different orders, that are vulnerable to rapid/flash floods production. These basins are distributed all across the Moldavian Plain and especially in the areas where the basins slope allows the concentration of water at the level of the minor river bed.

After superimposing the concentration stratum for settlements with the stratum of spatial and temporal distribution of concentration we identified 49 settlements located in different sub-basins which are vulnerable at flash floods production.

This kind of study represents a preliminary evaluation of the vulnerabilities for flash floods in the Moldavian Plain, study that indicates the settlements that can be affected by torrential rains. Following this study there is the possibility to develop a GIS methodology to model the rain-leakage process to anticipate the necessary water quantity for leakage and the integration of versant leakage in order to estimate the expected flash flood magnitudes. It is possible though to forecast the precipitations for a certain day and, by knowing the previous conditions oh humidity and the terrain characteristics, to estimate the quantity of water which will contribute to the flash flood; then the spatial and temporal leakage of the respective quantity can be modelled.

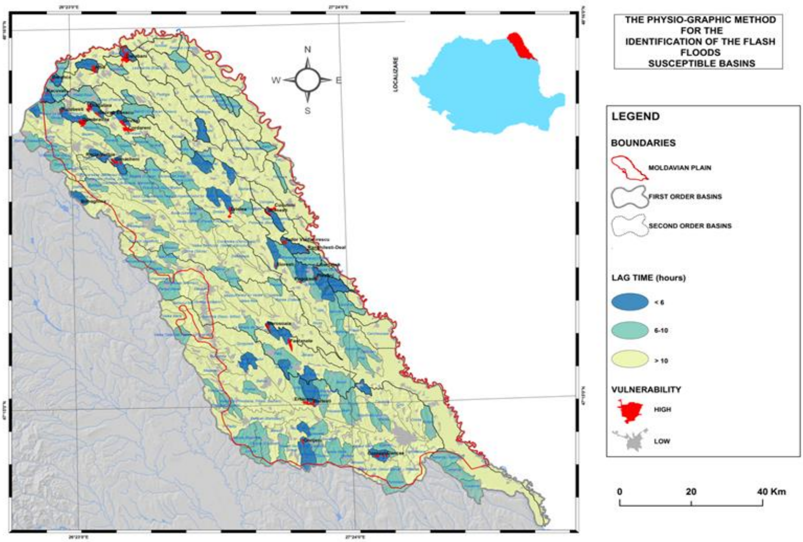


Fig. 6.71 The susceptible basins for flash floods in the Moldavian Plain based on the physio-graphic method

The geographic position of the analyzed zone and the torrential rains determined by the cyclonal activity specificity in this area generate favourable conditions which may trigger flash floods in all the 73 sub-basins. The increased precipitations in short time produce very high discharges that, in most of the cases, cannot be overtaken by the minor river beds. In the case of direct exposed localities the maintaining of the transit capacity in the river bed plays a maximum importance role to prevent inundations.

Based on certain correlations one can establish thresholds of the precipitations characteristics (quantity, duration) that can trigger flash floods. During forecasting or recording in the operative sector for the previous established values there is the possibility of immediate warning for the decision-makers which can also estimate the gravity of the event's risks.

4. CONCLUSIONS

In the Moldavian Plain and the immediate vicinities the annual precipitations average is 521.7 mm. On this relatively narrow space of the studied zone the precipitations' territorial variations are significant with respect to quantities which results in the delineation of some distinct, general view points:

- the atmospheric precipitations decrease slightly from west to east as a consequence of altitude lowering in this direction and the higher frequency of humid masses of air in the west; the air masses are in general of Atlantic origin and, toward east, they become slightly drier and thus imposing the west to east difference. The presence of foehnization on the western side controls the precipitations differences which, in consequence, do not become notably higher on the eastern side as related to the vertical pluviometric gradients in the Moldavian Plateau;

- the higher altitude zones have an increased pluviometric input (Ibăneşti Hills and Darabani Hills, in the north: Pomârla 623.8 mm; Copalău- Cozancea - Guranda Hills, in the centre: Cristeşti 585.3 mm and Nicolae Bălcescu 564.8 mm);

- the lower altitude zones record the most reduced precipitations quantities over the year. Among them we notice: a north-eastern sector in the Upper Jijia Plain, ac. White Horse 456 mm, Stânca 459 mm and a south-western sector, "in the shadow" of Great Hill-Hârlău (at Tansa 467.20 mm, Goat's Horns 473 mm). A third sector of low precipitations runs along the Prut Valley;

- there is a stretch of alternating sectors with higher precipitations at increased altitudes and lower precipitations at decreased altitudes; this succession is well evidenced on the NW – SE direction. The versants exposed to the more humid air masses for NW receive more precipitations while the versants exposed to SE, receive less precipitations and both types of air masses are controlled by foehnization processes in their movement; notable differences between the versants exposed to air advection and the ones not exposed to air advection are observed in the case of maritime origin air masses.

The annual precipitations regime is complex, yet one can notice the existence of two pluviometric maximums (a main one in June and a secondary one in November) and two pluviometric minimums (a main one in January and secondary one in October);

In the case of torrential rains we notice a relative uniformization of the frequencies' values that develop on a wide intensities interval with higher values toward the mid-summer. As far as the vulnerability is concerned, in the Moldavian Plain, as reported to the rains' intensity we notice that the northern half of the Plain is under medium vulnerability while the southern half is under high vulnerability.

The increase of the average annual discharge from spring to effluences, in direct report with increase of the tributaries number and the surface of the watershed surface is a general characteristic of the Moldavian Plain. For example, Jijia, the main collector of the studied sub-region records 0.67m^3/s at Dorohoi, 2.25 m^3/s at Todireni, 6.83 m^3/s at Victoria and 12.3 m^3/s at Chipereşti. The increase gradient is, in average, 1.75 m^3/s on 1000 km^2. Due to the physical-geographic conditions where the hydrographic basins develop the increase in discharge as reported to the overall surface is biased with noticeable differences.

The most important floods in the Moldavian Plain, between 1960-2011, appeared, in general in summer from June to July. In the above mentioned period, important floods appeared in: 1961, 1965, 1969, 1970, 1973, 1974, 1978, 1979, 1980, 1981, 1985, 1988, 1989, 1991, 1993, 1996, 2005, 2008 and 2010 with certain differences as a function of local conditions.

Regarding the medium duration of the floods we notice that on the rivers of the Moldavian Plain they rarely exceed 4 days, in great majority one day or two. The most floods were registered on the interior rivers, respectively 62.9% and only 27.1% on Prut. In the Moldavian Plain the hydrologic risk is considerable and it manifests not only on the main streams but also on the affluents. The geographic position of the plain and the torrential rains determined by the cyclonical activity specificity of this zone creates favourable conditions for the appearance of flash floods in 73 basins. The increased precipitations quantities in short time produce very high debits, debits which, in the majority of occasions cannot be delivered by the minor river beds. In the case of the 49 localities that are directly exposed the maintaining of the transit capacity for the river bed is of maximum importance to prevent inundations.

The climatic change and irregular territorial development that is insufficiently planned for inundations prevention and the increased erosion potential result in economical and social vulnerabilities as far as the floods risk in concerned is the Moldavian Plain.

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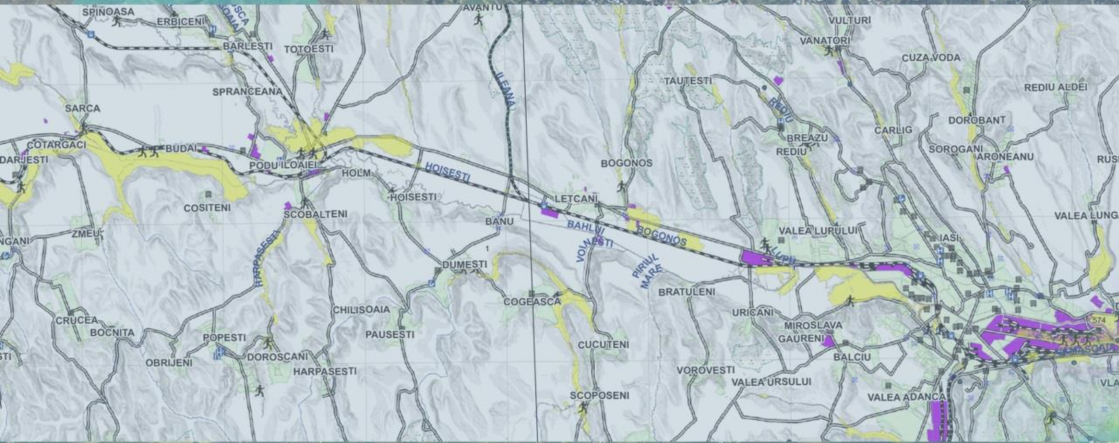
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574